Diss. ETH No. 11704

Lean Meat (Beef, Pork, Veal and Chicken) as a Source of Trace Elements and Vitamins (Iron, Zinc, Thiamin, Riboflavin and α-Tocopherol) in Switzerland, and Efficacy of Feeding Supplemental Vitamin E and C

A dissertation submitted to the
SWISS FEDERAL INSTITUTE OF TECHNOLOGY ZURICH
for the degree of
Doctor of Natural Sciences

presented by

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Zurich, 1996

Meinen Eltern und Brüdern

Danksagung

Mein herzlicher Dank gilt Herrn Prof. Dr. C. Wenk für die Überlassung des Themas und die Betreuung der vorliegenden Arbeit sowie für die Übernahme des Referates.

Herrn Prof. Dr. M. Kreuzer möchte ich meinen besten Dank aussprechen für die Übernahme des Korreferates und für die wertvollen Anregungen bei der Abfassung der Arbeit.

Bedanken möchte ich mich ebenfalls bei C. Brodhag, Dr. U. Moser, R. Rettenmaier, Dr. W. Schüep und Dr. H. Weiser (Hoffmann-La Roche, Basel) für die Unterstützung bei den Vitaminanalysen.

Bei P. Fahrni, Dr. D. Guidon und Dr. T. Rihs (RAP, Eidgenössische Forschungsanstalt für Nutztiere, Posieux) bedanke ich mich für die Eisen- und Zinkanalysen.

Mein besonderer Dank gilt dem Bundesamt für Gesundheitswesen, insbesondere Dr. J. Lüthy, der Herzer-Stiftung und der Stiftung zur Förderung der Ernährungsforschung in der Schweiz für die finanzielle Unterstützung.

Herzlich bedanken möchte ich mich auch bei Meret Memmen und Corinne Senaux für die Unterstützung bei den Analysen. Dr. Cristina Cardoso und Paolo Colombani danke ich für die sorgfälltige Durchsicht meiner Arbeit. Bei Aliette Freléchoz und Hocine Hellal bedanke ich mich für die französiche Übersetzung der Zusammenfassung.

Ferner danke ich allen KollegInnen, insbesondere aber Myrtha Arnold, Dr. Giuseppe Bee, Monica Casutt, Monique Dupuis, Stefan Gebert, Christine Feiss, Bruno Jörg, Francisca Jörger, Jana Kägi, Dr. Martina Kuhnt, Dr. Andrea Machmüller, Dr. Ruth Messikommer, Marty Porter, Dr. Franz Sutter und Dr. Dirk Werling, die durch ihre Hilfe zum Gelingen dieser Arbeit beigetragen haben.

Besonders bedanken möchte ich mich auch bei meinem Freund Thomas Asshauer für sein Verständnis und die moralische Unterstützung.

TABLE OF CONTENTS

1. Summary

In the present study, the contribution of the average lean meat consumption (beef, pork, veal and chicken) in Switzerland in 1995 to meet the requirements for selected trace elements (iron and zinc) and vitamins (thiamin, riboflavin and α-tocopherol) was calculated. For that purpose, the nutrient content of the following meat cuts was examined: pork (chop and shoulder), beef (prime rib and shoulder), veal (chop) and chicken (breast and thigh). Sample size of every meat cut was 25 pieces. From the beef prime rib and chop (pork and veal) samples the longissimus dorsi muscle was separated and the other meat cuts were trimmed of visible fat, skin and connective tissue. In all samples iron, heme iron, zinc, thiamin (vitamin B_1), riboflavin (vitamin B_2) and α-tocopherol (vitamin E) were analyzed. Except in beef shoulder, the thiamin and riboflavin content was not determined. In addition, the efficacy of the same vitamin E supplementation to pig and laying hen feeds, in order to increase the α-tocopherol contents of the respective animal products, was studied. Finally, it was examined whether a high supplementation of pig diet with vitamin E or C influenced the amount of vitamins (α-tocopherol, retinol, thiamin and riboflavin) in liver and longissimus dorsi muscle and the vitamin retention after heating the samples.

Beef and pork shoulder were the best sources of iron, heme iron and zinc. Pork and veal chop and chicken were relatively poor in these trace elements. The heme iron contents correlated with the zinc contents of the examined meat cuts within animal species. The correlation coefficients for the different beef, pork and chicken cuts were 0.48, 0.81 and 0.91, respectively. With an average daily lean meat consumption of 105 g (beef, pork, veal and chicken), iron and zinc intake were about 1.1 mg/d and 3.8 mg/d, respectively. Recommendations given by the German Nutrition Society for daily iron intake were met to 11% (men) and 7% (women) and for zinc intake to 25% (men) and 32% (women). Considering the modified Monsen model, the intake of available iron ranged between 0.1-0.3 mg/d. The requirement for absorbed iron was met in the range of 10-30% and 7-20% for men and women, respectively. Taking into account a zinc absorption efficiency

from meat of about 20-36%, the intake of available zinc ranged between 0.8-1.4 mg/d. The daily requirement for absorbed zinc was covered to 32-56%.

Pork was the best thiamin source (0.8 mg/100 g) and there was no significant difference in thiamin content of longissimus dorsi and shoulder muscles. Also, no difference in thiamin content of chicken breast and thigh was found. In contrast, the riboflavin content significantly differed between the muscles within species (pork and chicken) examined. Considering the average daily lean meat consumption, thiamin and riboflavin intake were approximately 0.5 mg/d and 0.2 mg/d, respectively. Recommendation for daily thiamin intake was met to 25% (men) and to 29% (women). Pork itself had a contribution of about 23% (men) and 27% (women). Recommendation for daily riboflavin intake was met to 10% (men) and 11% (women).

Chicken thigh had the highest α-tocopherol content (1.2 mg/100 g), followed by chicken breast and pork shoulder. The lowest concentrations were found in longissimus dorsi muscle from pork, beef, veal and beef shoulder. Regarding the average daily lean meat consumption, α-tocopherol intake was approximately 0.4 mg/d. The recommendation for daily vitamin E intake was met to 3%.

The highest coefficients of variation were calculated for α-tocopherol (CV: 35-62%) and the lowest for riboflavin (CV: 11-19%) and zinc (CV: 8-17%). The coefficients of variation for veal iron and heme iron contents were relatively high compared to those of the other meat cuts. The reason might be different veal feeding regimens. In general, the coefficients of variation were higher for those nutrients in meat, which are affected by the feed composition, compared to those mainly genetically determined.

Supplementation of diets for pigs and laying hens with 200 mg α-tocopherol acetate/kg feed significantly increased the α-tocopherol content in all examined products. The α-tocopherol accumulation differed according to the following ranking: egg yolk > liver > adipose tissue > longissimus dorsi muscle. The α-tocopherol ratios were 28.8, 7.3, 0.9 and 1.2 mg/MJ for egg yolk, liver, adipose tissue and longissimus dorsi of the vitamin E supplemented groups, respectively. The results showed that pork (longissimus dorsi)

from animals fed a vitamin E enriched diet is not an important supplier of vitamin E. On the contrary, egg yolk became a good source of vitamin E for human nutrition by dietary modification. A further trial with pigs showed that not only a vitamin E supplementation, but also a vitamin C supplementation of pig diets increased ($P<0.05$) liver α-tocopherol concentration. After heating, the liver samples of both treatment groups (vitamin E or C) and the longissimus dorsi muscle samples of the vitamin C group showed increased riboflavin retention ($P<0.05$). The supplemented and control groups did not show differences regarding retention of α-tocopherol, retinol and thiamin in heated liver and *longissimus dorsi*.

2. Zusammenfassung

In der vorliegenden Studie wurde der Beitrag des durchschnittlichen Verzehrs an magerem Fleisch (Rind-, Schweine-, Kalb- und Hähnchenfleisch) in der Schweiz im Jahr 1995 zur Bedarfsdeckung an ausgewählten Spurenelementen (Eisen und Zink) und Vitaminen (Thiamin, Riboflavin und α-Tocopherol) berechnet. Für diesen Zweck wurde der Nährstoffgehalt folgender Fleischstücke untersucht: Schweine- (Kotelett und Schulter), Rind- (Hohrückensteak und Schulter), Kalb- (Kotelett) und Hähnchenfleischproben (Brust und Schenkel). Pro Fleischstück wurden 25 Proben untersucht. Aus den Hohrükkensteak- und Kotelettstücken (Schwein und Kalb) wurde der Musculus longissimus dorsi herausgelöst, und von den anderen Fleischstücken wurde das sichtbare Fett, Haut und Bindegewebe abgetrennt. In allen Proben wurde Eisen, Hämeisen, Zink, Thiamin (Vitamin B_1), Riboflavin (Vitamin B_2) und α-Tocopherol (Vitamin E) analysiert. Nur in der Rindsschulter wurde der Thiamin- und Riboflavingehalt nicht bestimmt. Zusätzlich wurde die Wirksamkeit einer gleich hohen Vitamin E-Supplementierung des Schweine- und Legehennenfutters in Bezug auf die Vitamin E-Anreicherung in den entsprechenden tierischen Produkten getestet. Schließlich wurde untersucht, ob eine hohe Supplementierung des Schweinefutters mit Vitamin E oder C die Vitamingehalte (α-Tocopherol, Retinol, Thiamin, und Riboflavin) in Leber und Musculus longissimus dorsi und die Vitaminretention nach Erhitzen der Proben beeinflußt.

Rindfleisch und Schweineschulter waren die besten Eisen-, Hämeisen- und Zinkquellen. Musculus longissimus dorsi vom Schwein und Kalb und Hähnchenfleisch waren relativ arm an diesen Spurenelementen. Die Hämeisengehalte korrelierten mit den Zinkgehalten der untersuchten Fleischstücke innerhalb einer Tierart. Die Korrelationskoeffizienten für die verschiedenen Rindfleisch-, Schweinefleisch-, und Hähnchenfleischstücke betrugen 0.48, 0.81 und 0.91. Mit einem durchschnittlichen, täglichen Verzehr an magerem Fleisch von 105 g (Rind-, Schwein-, Kalb- und Geflügelfleisch), betrug die Eisen- und Zinkaufnahme 1.1 mg/Tag bzw. 3.8 mg/Tag. Die Empfehlungen der deutschen Gesellschaft für Ernährung (DGE) für eine tägliche Eisenaufnahme wurden zu 11% (Männer) und zu 7% (Frauen) und für die Zinkaufnahme zu 25% (Männer) und zu 32% (Frauen) gedeckt. Unter Berücksichtigung des modifizierten Monsenmodells betrug die Aufnahme an ver-

fügbarem Eisen 0.1-0.3 mg/Tag. Die Deckung des Bedarfs an absorbierbarem Eisen lag im Bereich von 10-30% (Männer) bzw. im Bereich von 7-20% (Frauen). Wird eine Zinkabsorption aus dem Fleisch von 20-36% angenommen, variierte die Aufnahme an verfügbarem Zink zwischen 0.8-1.4 mg/Tag. Der tägliche Bedarf an verfügbarem Zink wurde zu 32-56% gedeckt.

Schweinefleisch war die beste Thiaminquelle (0.8 mg/100 g) und es konnte kein signifikanter Unterschied im Thiamingehalt des Musculus longissimus dorsi und den Schultermuskeln nachgewiesen werden. Ebenfalls wurde kein Unterschied im Thiamingehalt der Hähnchenbrust und des Hähnchenschenkels nachgewiesen. Hingegen variierte der Riboflavingehalt signifikant zwischen den Muskeln einer Tierart (Schwein und Hähnchen). Mit dem durchschnittlichen, täglichen Verzehr an magerem Fleisch betrug die Thiamin- und Riboflavinaufnahme ca. 0.5 mg/Tag bzw. 0.2 mg/Tag. Die Empfehlung für eine tägliche Thiaminaufnahme wurde zu 25% (Männer) bzw. zu 29% (Frauen) gedeckt. Das Schweinefleisch allein hatte einen Anteil von 23% (Männer) bzw. 27% (Frauen). Die Empfehlung für die tägliche Riboflavinaufnahme wurde zu 10% (Männer) bzw. zu 11% (Frauen) gedeckt.

Hähnchenschenkel hatte den höchsten α-Tocopherolgehalt (1.2 mg/100 g) gefolgt von Hähnchenbrust und Schweineschulter. Die niedrigsten Konzentrationen wurden im M. longissimus dorsi vom Schwein, Rind, Kalb und in der Rindsschulter nachgewiesen. Mit dem durchschnittlichen, täglichen Verzehr an magerem Fleisch betrug die α-Tocopherolaufnahme ca. 0.4 mg/Tag. Die Empfehlung für die tägliche Vitamin E-Aufnahme wurde zu 3% gedeckt.

Die höchsten Variationskoeffizienten wurden für die α-Tocopherol- (VK: 35-62%) und die niedrigsten für die Riboflavin- (VK: 11-19%) und Zinkwerte (VK: 8-17%) berechnet. Die Variationskoeffizienten für die Eisen- und Hämeisengehalte im Kalbfleisch waren relativ hoch verglichen mit denen der anderen Fleischstücke. Die Ursache ist möglicherweise die unterschiedliche Fütterung der Kälber. Allgemein waren die Variationskoeffizienten für die Nährstoffe im Fleisch, die durch die Futterzusammensetzung beeinflußbar sind, höher im Vergleich zu den Variationskoeffizienten der Nährstoffe, deren Gehalte hauptsächlich genetisch festgelegt sind.

Die Supplementierung des Schweine- und Legehennenfutters mit 200 mg α-Tocopherolacetat/kg führte zu einem signifikanten Anstieg des α-Tocopherolgehaltes in allen untersuchten Produkten. Die α-Tocopherolakkumulierung unterschied sich gemäß folgender Rangordnung: Eigelb > Leber > Fettgewebe > Musculus longissimus dorsi. Die Nährstoffdichten betrugen 28.8, 7.3, 0.9 und 1.2 mg α-Tocopherol/MJ für Eigelb, Leber, Fettgewebe, und Musculus longissimus dorsi der jeweiligen mit Vitamin E supplementierten Gruppe. Diese Ergebnisse zeigen, daß Schweinefleisch (M. longissimus dorsi) von Tieren mit supplementierten Futterrationen kein bedeutender Vitamin E-Lieferant ist. Hingegen wurde Eigelb durch fütterungsbedingte Modifikation zu einer guten Vitamin E-Quelle. Eine weitere Studie mit Schweinen zeigte, daß nicht nur eine Vitamin E-Supplementierung sondern auch eine Vitamin C-Anreicherung des Futter die α-Tocopherolkonzentration in der Leber erhöhte ($P<0.05$). Nach dem Erhitzen zeigten die Leberproben beider Behandlungsgruppen (Vitamin E oder C) und die Longissimus dorsi Proben der Vitamin C Gruppe eine höhere Riboflavinretention ($P<0.05$). Die supplementierten Gruppen und die Kontrollgruppe zeigten keine Unterschiede bezüglich der α-Tocopherol-, Retinol- und Thiaminretention in den erhitzten Leber und Longissimus dorsi Proben.

3. Résumé

Dans la présente étude, la contribution de la viande maigre (boeuf, porc, veau et poulet) à la couverture des besoins en oligo-éléments (fer et zinc) et en vitamines (thiamine, riboflavine et α-tocophérol) a été calculée par rapport aux quantités de viande consommées en Suisse pour l'année 1995. La teneur en éléments nutritifs a été analysée dans les morceaux de viandes suivants: porc (côtelette et épaule), boeuf (côte couverte et épaule), veau (côtelette) et poulet (bréchet, cuisse). Vingt-cinq échantillons par morceau de viande ont été analysés. Le muscle longissimus dorsi a été découpé des côtes couvertes et des côtelettes et la graisse visible, la peau et le tissu conjonctif ont été écartés des autres morceaux de viande. Dans tous les échantillons, le fer héminique, le zinc, la thiamine (vitamine B_1), riboflavine (vitamine B_2) et l'α-tocophérol (vitamine E) ont été analysés. Pour ce qui est des échantillons d'épaule de boeuf, la thiamine et la riboflavine n'ont pas été déterminés. L'efficacité de la même supplémentation en vitamine E dans les aliments pour porc et poules pondeuses pour augmenter la teneur en α-tocophérol dans les produits résultants a été étudiée. L'influence d'une supplémentation élevée en vitamine E ou C dans l'aliment pour porc sur le contenu en vitamines (α-tocophérol, retinol, thiamine et riboflavine) du foie et du muscle longissimus dorsi et sur la rétention des vitamines après cuisson dans ces morceaux a été examinée.

La viande de boeuf et l'épaule de porc étaient les meilleures sources en fer, fer héminique et zinc. Le muscle longissimus dorsi du porc et du veau ainsi que la viande de poulet étaient relativement pauvres en ces oligo-éléments. Le contenu en fer héminique est positivement corrèlé avec le contenu en zinc des différents morceaux de viande examinés pour la même espèce animale. Le coefficient de corrélation pour les différentes espèces animales (boeuf, porc et poulet) était respectivement de 0.48, 0.81 et 0.91. Avec une consommation moyenne en viande maigre de 105 g/jour (boeuf, porc, veau et poulet), la prise journalière en fer et en zinc est alors respectivement de 1.1 mg et de 3.8 mg. Ces valeurs couvrent 11% chez les hommes et 7% chez les femmes des besoins journaliers en fer recommandés par la DGE (Société allemande de nutrition). En ce qui concerne le zinc, 25% des apports journaliers sont couverts chez

l'homme et 32% chez la femme. En prenant en considération le model modifié de Monsen, la prise en fer disponible est de 0.1-0.3 mg/jour. Le recouvrement des besoins en fer absorbable était de 10-30% pour les hommes et de 7-20% pour les femmes. Pour une absorption en zinc de 20-36% à partir de la viande, la prise journalière en zinc disponible variait de 0.8 à 1.4 mg. Le besoin journalier en zinc disponible était couvert à 32-56%.

La viande de porc était la meilleure source en thiamine (0.8 mg/100 g) et aucune différence significative n'a été observée entre le muscle longissimus dorsi et l'épaule. Aucune différence dans la teneur en thiamine entre le bréchet et la cuisse de poulet n'est à signaler. Par ailleurs le contenu en riboflavine variait significativement entre les espèces (porc et poulet). Avec une consommation journalière moyenne en viande maigre, la prise en thiamine et en riboflavine serait respectivement d'environ de 0.5 mg et 0.2 mg. Les recommandations journalières pour les besoins en thiamine sont couvertes à 25% (hommes) et à 29% (femmes). La viande de porc seule couvre une part de 23% pour les hommes et de 27% pour les femmes. Les recommandations journalières en riboflavine étaient couverte à 10% pour les hommes et à 11% pour les femmes.

Les cuisses de poulets avaient le plus grand contenu en α-tocophérol (1.2 mg/100g) suivit du bréchet et de l'épaule de porc. Les plus faibles concentrations ont été trouvées dans le muscle longissimus dorsi du porc, boeuf, veau et dans l'épaule de boeuf. Pour une consommation journalière moyenne en viande maigre, la prise en α-tocophérol serait donc de 0.4 mg. La prise journalière en vitamine E recommandée serait alors couverte à 3%.

Les plus grands coefficients de variation étaient pour l' α-tocophérol (35-62%) et les plus faibles pour la riboflavine (18-19%) et le zinc (8-17%). Les coefficients de variations pour le fer et le fer héminique dans la viande de veau étaient relativement élevés en comparaison avec les autres viandes. Les causes de ces variations sont probablement dues aux différentes alimentations des veaux. En général, les éléments nutritifs de la viande influencés par l'alimentation des animaux présentaient des

coefficients de variation plus élevés que les éléments nutritifs déterminés génétiquement.

La supplémentation des aliments pour porc et poules pondeuses avec 200 mg d'α-tocophérolacetat/kg a entraîné une augmentation significative en α-tocophérol dans tous les produits analysés. L'accumulation en α-tocophérol se différencie dans l'ordre suivant: jaune d'oeuf > foie > tissu adipeux > muscle longissimus dorsi. Les concentrations relatives en α-tocophérol étaient respectivement de 28.8, 7.3, 0.9 et 1.2 mg α-tocophérol/MJ pour le jaune d'oeuf, le foie, les tissus adipeux et le muscle longissimus dorsi. Ces résultats ont montré que les muscles longissimus dorsi des porcs ayant reçu des rations supplémentées ne fournissent pas beaucoup de vitamine E. Au contraire le jaune d'oeuf est devenu une bonne source en vitamine E à travers la modification de l'alimentation des poule. Une étude plus poussée sur des porcs supplementé en vitamin E ou en vitamin C a montré que non seulement la supplémentation en vitamine E dans l'aliment, mais aussi celle de la vitamine C augmente la concentration en α-tocophérol dans le foie ($p<0.05$). Après cuisson, les échantillons de foie des deux groupes de traitements et les échantillons de muscle longissimus dorsi des animaux ayant reçu une supplémentation en vitamine C, ont montré une plus grande rétention en riboflavine ($p<0.05$). En ce qui concerne la rétention en α-tocophérol, retinol et thiamine, les échantillons cuits de foie et du muscle longissimus dorsi des groupes supplémentés n'étaient pas différents de ceux groupe contrôle.

4. General Introduction

An adequate supply of vitamins and trace elements is important for the maintenance of good health (German Nutrition Society, 1995). Severe vitamin deficiencies like scurvy and beriberi are rare in industrialized countries like Switzerland. However, a marginal supply of different nutrients with the possible risk of subclinical deficiencies, also occurs in these countries (Rufer-Meineke, 1991). In the Third Swiss Nutrition Report the nutrient intake of the Swiss, based on average food consumption, is estimated (Rham, 1991). Although, the average thiamin and riboflavin intakes in Switzerland were higher than the recommendations of the German Nutrition Society (1995), different studies provide evidence that some population groups are still at risk of an inadequate supply (Rufer-Meineke, 1991). For example, Schlettwein-Gsell et al. (1991) reported that many elderly people had a low thiamin and riboflavin intake.

The iron and zinc intake seems to be sufficient. However, only considering the absolute amount of trace elements in food, their contribution to trace element supply can not be judged, because the availability of these trace elements has to be taken into account (Kiefer and Sieber, 1991). Jacob Sempach (1995) investigated the nutrient intake and iron status of young women living in Zurich. 11 % of the young women had a latent iron deficiency.

In industrialized countries meat is an important supplier of many nutrients. For example, meat has long been recognized as a good source of B-vitamins and trace elements like iron and zinc (Briggs and Schweigert, 1990). In many food composition tables (McCance and Widdowson, 1991; Souci et al., 1994; Elmadfa et al., 1996), the vitamin and trace element contents of meat have been described. However, only few newer data are available. Since animal breeds and feeding practice were modified over the past years, it is also possible that the nutrient contents in meat have changed. For example, it is well known that the vitamin E content of animal feed influences the vitamin E content of animal products (Arnold et al., 1993; Asghar et al., 1991b, King et al., 1995). Additionally, information about muscle related differences in vitamin and trace element content is limited. For judging the contribution of a food as an iron and zinc supplier, it is not only important to have information about the absolute content of these elements, but also about the availability. Meat contains heme iron and nonheme iron. Since the availability of these two iron components is very different, it is important to obtain data about

the heme and nonheme iron content in meat. Finally, in most studies, meat samples were directly selected at the abattoir. Since nutrients, especially water-soluble vitamins, can be lost with the meat broth (Bässler et al., 1992), it is also important to provide further information about the vitamin contents in meat sold at the retail level.

The objective of the present study was to examine the contents and variability of several vitamins (thiamin, riboflavin and tocopherol) and trace elements (iron and zinc) in different meat cuts (beef, pork, chicken and veal), available at the retail level in Switzerland. Furthermore, the contribution of the average meat consumption in Switzerland in the year 1995 to meet the requirements for these vitamins and trace elements was calculated. Also, the efficacy of a vitamin E supplementation (pigs and laying hens) on the α-tocopherol content of animal products and their vitamin E supply for human nutrition was examined. Finally, it was determined whether a high supplementation of pig diet with vitamin E and C influences the amount of vitamins (α-tocopherol, retinol, thiamin and riboflavin) in liver and pork longissimus dorsi muscle and whether dietary vitamin E and C supplementation affects vitamin retention after heating of liver or chop samples.

5. Contribution of the Average Meat Consumption in Switzerland Towards Fulfilling the Requirements for Iron and Zink

Based on:

Monika Leonhardt and Caspar Wenk, **1996.**

Proc. 5th International Congress on Trace Elements in Medicine and Biology,

February 4th-7th, Méribel, France (in press)

ABSTRACT

The objective of the present study was to estimate the contribution of the average lean meat consumption in Switzerland (1995) to meet the requirements for absorbed iron and zinc. Iron, heme iron and zinc contents were analyzed in following meat cuts: pork (chop and shoulder), beef (prime rib and shoulder), veal (chop) and chicken (breast and thigh). Beef and pork shoulder were the best sources of iron, heme iron and zinc. Pork and veal chop and chicken were relatively poor in these trace elements. With an average daily lean meat consumption of 105 g, iron and zinc intake were about 1.1 mg/d and 3.8 mg/d, respectively. Recommendations given by the German Nutrition Society for daily iron intake were met to 11% (men) and 7% (women) and for zinc to 25% (men) and 32% (women). Considering the modified Monsen model, the intake of available iron ranged between 0.1-0.3 mg/d. The requirement for absorbed iron was met in the range of 10-30% and 7-20% for men and women, respectively. Taking into account a zinc absorption efficiency from meat of about 20-36%, the intake of available zinc ranged between 0.8-1.4 mg/d. The daily requirement for absorbed zinc was covered to 32-56%. In conclusion, even the relatively small amount of meat consumed in Switzerland was an important source of available iron and zinc, especially for people with low iron and zinc status.

INTRODUCTION

Iron deficiency is the most prevalent nutritional deficiency. The estimated number of people world-wide suffering from iron deficiency anaemia (IDA) is about 500 million and many more have empty iron stores. In developing countries, the prevalence of IDA is particularly high (British Nutrition Foundation, 1995). The reasons are that most of these people consume a diet with low quantities of meat and their major iron sources are cereals and vegetables with poor availability of dietary iron (Lerner and Iancu, 1988; Carpenter and Mahoney, 1992). However, also in developed countries IDA is high in children below two years of age, adolescent girls, menstruating women and pregnant women (Carpenter and Mahoney, 1992; British Nutrition Foundation, 1995). Meat, fish, poultry and offal are the only foods that contain the better available heme iron besides the inorganic iron (nonheme iron) (Latunde-Dada and Neale, 1986; Oster, 1994; Carpenter and Mahoney, 1992). Meat contains no iron absorption reducing factors like phytate, tannins, oxalate and fibres (Oster, 1994). In addition, animal tissue and ascorbic acid are the only dietary factors that facilitate the nonheme iron absorption, especially when consumed together with a strongly inhibiting food such as maize porridge (Hurrell et al., 1988).

Meat is not only an important source of available iron, but also of zinc. It is well known that absorption of dietary zinc from animal protein based meals is higher compared to wholegrain cereal based meals (King and Turnland, 1989). The main reason is, as described for iron, the absence of zinc absorption inhibiting factors like phytate and fibres. In addition, it has been shown that meat protein enhances zinc absorption from phytate containing meals due to its higher affinity for zinc compared to phytate (Kirchgeßner et al., 1990). Zinc deficiency syndromes like reduced growth rate in children and infants and impaired immune function were first reported from countries like Iran and Egypt, where most people consumed great quantities of wholegrain wheat bread combined with low quantities of meat (Solomons et al., 1979). However, population groups in industrialized countries with a low energy intake and a high intake of foods rich in fat and sugar must also be considered at risk of inadequate zinc intake (Sandström, 1991).

The objective of our study was to estimate the contribution of the average lean meat consumption (beef, pork, chicken and veal) in Switzerland to meet the requirement for absorbed iron and zinc.

MATERIALS AND METHODS

Materials

The following meat cuts were purchased from 25 different supermarkets (Migros and Coop) and butcher's shops in Zurich (Switzerland): pork (chop and shoulder), beef (prime rib and shoulder), veal (chop) and chicken (breast and thigh). Pork chop samples were purchased in July and August 1994, beef prime rib samples in September 1994 and pork shoulder, beef shoulder, veal chop and chicken (breast and thigh) in the time of January to March 1995. In every shop, three pork chops and two veal chops, one beef prime rib and shoulder piece, one pork shoulder and one chicken (whole bird) were bought. The different pork chop and veal chop samples of one shop were combined to form one pork chop and one veal chop sample, respectively. For beef, pork and veal only fresh samples were taken. For chicken, fresh samples were also preferred. However, if no fresh samples were available, frozen samples were bought. Therefore, 16 fresh and 9 frozen birds were chosen. The frozen whole birds were thawed overnight in a refrigerator (4° C) and then prepared for analyses.

Sample size of every meat cut was 25 pieces. From beef prime rib, pork chop and veal chop, the longissimus dorsi muscle was separated and the other meat cuts were trimmed of visible fat, connective tissue. From chicken (whole bird), thigh and breast were separated and also trimmed of visible fat, connective tissue and skin.

Chemical Analyses

The meat samples (lean muscle) were cut into small pieces with special iron and zinc free scissors (zirconiumoxide). For iron and zinc determination the samples were frozen and lyophilized. They were then thoroughly homogenized with a highcentrifugal mill (Retsch typ zm1, Arlesheim, Switzerland) by using a titan piston and titan sieve. The freeze-dried, homogenized samples were dried, preashed and ashed three times in quartzglass

crucibles. Before the second and third ashing process, samples were treated with some drops of 20% ammonium nitrate solution. The ashes were cooked with 10 ml 25% hydrochloric acid for 20 min. After washing the rims of the quartzglass crucibles with deionized water, the solutions were cooked again for 10 min. The solutions were transferred into 100 ml glass flasks and filled up with deionized water (RAP, 1993a; 1993b). The solutions were sent to the Swiss Federal Research Station for Animal Production (RAP, Posieux, Switzerland), where iron and zinc were analyzed by atomic absorption spectrometry (Perkin Elmer AG, Rotkreuz, Switzerland).

Heme iron was determined by the alkaline haematin method from Karlsson and Lundström (1991). Minced meat samples were homogenized with 25 ml chilled extraction buffer. The solutions were transferred into 50 ml glass flasks and filled up with buffer. After an overnight storage at 4° C, the samples were filtered at room temperature. The filtrates (4 ml) were mixed with 400 µl of a 10% Triton X-100 solution and with 250 µl 5.0 M sodium hydroxide solution. After 5 min the absorption was read at 575 and 700 nm (Shimadzu spectrometer UV-160A, Kyoto, Japan). The heme iron concentration was calculated by using a haematin (haematin chloride) standard curve. The nonheme iron content was calculated as the difference between total iron (median of all values of one meat cut) and heme iron (median).

Calculation of the meat intake

The statistical per capita meat consumption (slaughter weight) in Switzerland (1995) was the basis for calculating the average lean meat consumption (Table 1). This is the amount of meat available in Switzerland under consideration of imported and exported meat, respectively. However, this amount still includes bones, adipose tissue and tendons, which are not used for human nutrition. Therefore, 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). The amount of lean meat was then related to the number of inhabitants (7.17 millions) in Switzerland in the year 1995. As shown in Table 1, pork, beef, veal and chicken (105 g) comprised about 85 % of the total meat consumption (123 g) in Switzerland.

Table 1. Per capita meat consumption in Switzerland in the year 1995

Meat (examined)	Consumption in tons (1995)[a]	Lean meat %	Meat consumption (per capita)[b] kg/year	g/day
Pork	**254516.4**	**55**	**19.52**	**53**
Beef	**120196.4**	**65**	**10.90**	**30**
Veal	**35898.0**	**66**	**3.30**	**9**
Poultry	78240.7	50	5.46	15
Chicken (85%)			**4.64**	**13**
Sum (pork, beef, veal and chicken)			**38.36**	**105**
Meat (not examined)				
Lamb, mutton, goat and horse-flesh	18182.9	70	1.79	5
Rabbits and meat of wild animals	9647.8	50	0.68	2
Fish and seafood	53839.9	44	3.33	9
Sum (all meat)				123

[a] slaughterweight (Swiss Meat Board, 1995)
[b] number of inhabitants: 7.17 millions

Calculation of the available iron and zinc intake

For calculating the intake of available iron provided by the average meat consumption the modified Monsen model was used (Monsen et al., 1978; Carpenter and Mahoney, 1992). In this model the heme iron absorption varies among 15-35% and is only dependent on the iron status. The nonheme iron absorption varies among 2-20% depending on iron status and intake of enhancing factors. Since no information about iron status and intake of iron absorption enhancing factors of the Swiss population is available, the whole range of iron absorption was considered. For estimating the intake of available zinc, the absorption data obtained from different radioisotope studies, carried out by Sandström and Cederblad (1980) and Gallaher et al. (1988) were considered. In these studies the zinc absorption efficiency from meat was about 20-36%. Data about the daily requirement for absorbed iron and zinc were obtained from Carpenter and Mahoney (1992) and King and Turnlund (1989), respectively.

To calculate significant differences ($P<0.05$) in iron, heme iron and zinc content of different meat cuts, the analysis of variance (ANOVA) was computed by using Statgraphics 5.0. Significance of means was determined using Bonferroni's Multiple

Range Test. The regression analysis (linear model) was also computed by using Statgraphics 5.0.

RESULTS

In Table 2 iron, heme iron, nonheme iron and zinc contents are shown. Beef had the highest concentrations of the examined trace elements. Iron content of beef shoulder and prime rib (m. longissimus dorsi) was nearly identical, whereas the concentrations of heme iron and zinc differed ($P<0.05$). Pork muscles were inhomogeneous in the examined trace elements concentrations. While pork shoulder muscles contained relatively large quantities of iron, heme iron and zinc, the m. longissimus dorsi was poorer in these trace elements ($P<0.05$). Chicken had particularly low contents of iron, heme iron and zinc. However, chicken thigh had higher contents than breast ($P<0.05$). The total iron and heme iron concentrations of veal chop samples (m. longissimus dorsi) were also low. The zinc content of m. longissimus dorsi (veal) was significantly higher compared to chicken and pork longissimus dorsi, but lower than that of beef and pork shoulder ($P<0.05$). The percentage of heme iron of the meat cuts ranged between 50 and 100%.

Fig. 1 shows the relation between heme iron and zinc contents. The correlation coefficients for the different beef, pork and chicken cuts were 0.48, 0.81 and 0.91, respectively. Meat cuts rich in heme iron such as beef and pork shoulder were also good sources of zinc.

In Table 3 the trace element intake provided by the average daily meat consumption in Switzerland in the year 1995 is shown. For calculating the average trace element intake, the mean of the two median values for each animal species (beef, pork and chicken) was used. With a daily meat consumption of 105 g, the iron intake was about 1.1 mg/d and the zinc intake was 3.8 mg/d. Recommendations for daily iron intake were met to 11% (men) and 7% (women) and for zinc to 25% (men) and 32% (women). With a daily iron intake of 1.1 mg/d, the intake of available iron ranged between 0.1-0.3 mg/d. The average meat consumption covered the requirement for absorbed iron to 10-30% and 7-20% for men and women, respectively. Taking into account a zinc absorption efficiency from meat of about 20-36%, the intake of available zinc ranged between 0.8-1.4 mg/d. The daily requirement for absorbed zinc was covered to 32-56% by meat consumption.

Table 2. Iron, nonheme iron, heme iron and zinc contents of different meat cuts[g]

Meat cuts	Iron (mg/100 g wet wt)				Nonheme iron	Heme iron (mg/100 g wet wt)				Heme iron[h]	Zinc (mg/100 g wet wt)			
	Mean	SD	Median	Range	mg/100 g wet wt	Mean	SD	Median	Range	%	Mean	SD	Median	Range
Pork														
L.d.m.	0.5[ab]	0.1	0.5	0.4-0.6	0.2	0.3[ab]	0.1	0.3	0.2-0.4	60	1.7[b]	0.2	1.7	1.3-2.2
Shoulder	1.3[c]	0.3	1.4	0.7-1.8	0.6	0.8[d]	0.3	0.8	0.4-1.4	57	5.3[de]	0.9	5.4	3.1-7.0
Beef														
L.d.m.	1.9[d]	0.5	1.7	1.2-3.4	0.6	1.2[e]	0.2	1.1	0.8-1.7	65	5.1[d]	0.8	5.2	3.7-6.6
Shoulder	1.8[d]	0.5	1.8	1.4-3.4	0.3	1.6[f]	0.3	1.5	1.0-2.2	83	5.8[e]	0.8	5.7	4.6-7.2
Chicken														
Breast	0.4[a]	0.0	0.4	0.3-0.5	0.2	0.2[a]	0.0	0.2	0.1-0.2	50	0.6[a]	0.1	0.7	0.5-0.7
Thigh	0.6[b]	0.1	0.6	0.5-0.8	0.1	0.5[c]	0.1	0.5	0.4-0.7	83	1.6[b]	0.1	1.6	1.4-1.9
Veal														
L.d.m.	0.4[ab]	0.2	0.4	0.2-1.0	0.0	0.4[bc]	0.2	0.4	0.2-0.8	100	2.5[c]	0.4	2.5	1.9-3.9

SD, Standard deviation; L.d.m., Longissimus dorsi muscle.

[a,b,c,d,e,f] Iron, heme iron and zinc contents (means) of the different meat cuts with unlike letters were significantly different ($P<0.05$).

[g]Only lean meat was analyzed. The sample size for each meat cut was 25 pieces.

[h]Heme iron expressed as percentage of total iron.

DISCUSSION

Iron, heme iron and zinc contents of the examined meat cuts

Compared to our values (Table 2) , several reported iron (2.1-2.7 mg/100 g wet wt) and heme iron values (1.5-2.2 mg/100 g wet wt) for beef were somewhat higher (Hazell, 1982; Schricker et al., 1982a; Carpenter and Clark, 1995). The iron and heme iron values for pork and chicken were comparable to our values. The main reason for the variety in the examined trace element contents might be different cattle breeds used in Switzerland compared to other countries. Similar to our results, Schricker et al. (1982a) found higher values for pork shoulder compared to pork m. longissimus dorsi, and Carpenter and Clark (1995) also reported higher iron and heme iron values for chicken thigh compared to chicken breast. Our found veal heme iron percentage was 100%. It is unlikely that the examined veal l.d.m. did not have any nonheme iron. However, Carpenter and Clark (1995) also reported beef heme iron percentage of total iron of 102%. They explained their findings by stating that the total iron content is probably underestimated.

Muscle specific differences in zinc content, especially for pork, were also reported by Schricker et al. (1982b) and Marchello et al. (1985). They showed that pork shoulder muscles contained greater amounts of zinc than leg and loin muscles. However, their zinc contents in pork shoulder were lower compared to our values, which were in the same range as described in Souci et al. (1989). As described previously, for calculating the average trace element intake (Table 3), the mean of the two median values for each animal species (pork, beef and chicken) was used. Since pork was very inhomogeneous in zinc content, with a calculated average zinc content of 3.5 mg/100 g wet weight (wet wt), the contribution of pork to meet the zinc requirement might be slightly overestimated, because other authors reported an average zinc content of pork in the range of 1.9-2.8 mg/100g wet wt (Schricker, 1982b; Seuss et al., 1988; Sandström, 1989; Souci et al., 1989; McCance and Widdowson, 1991; Kirchgessner et al., 1994). However, for a final determination of the average pork zinc content (lean muscle), the total lean meat of a pig must be analyzed as described by Kirchgessner et al. (1994).

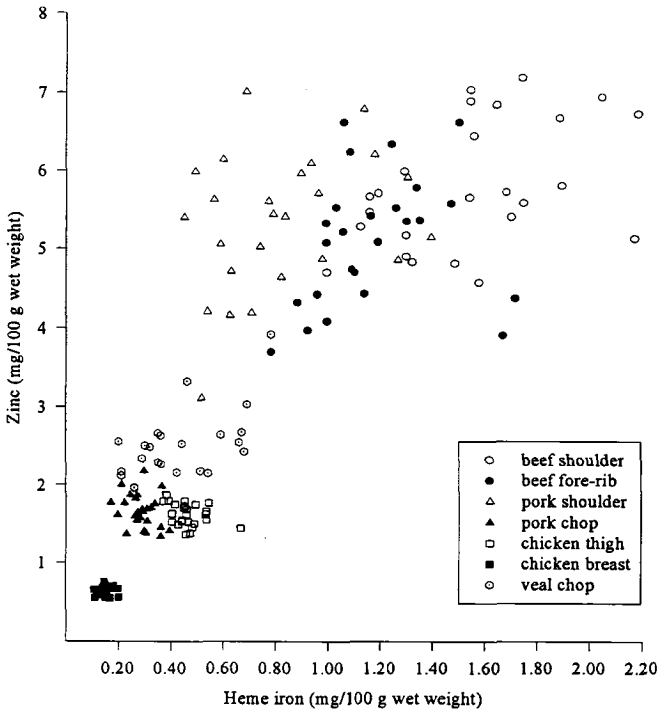

Fig. 1. Relation between heme iron and zinc contents of different meat cuts.

Intake of available iron

As shown in Table 3, even the small amount of meat consumed in Switzerland was an important source of available iron, especially for people with low iron stores. With an average meat consumption of 105 g, the requirement for absorbed iron would be theoretically met to 30% and 20% for iron-deficient men and women, respectively.

However, the modified Monsen model (Monsen et al., 1978; Carpenter and Mahoney, 1992) for estimating the intake of available iron is quite simple. Hunt et al. (1994)

criticized that the nonheme iron absorption enhancing effect of ascorbic acid is presumably overestimated. Hallberg et al. (1992) have shown in their study that calcium not only reduced the nonheme iron absorption, but also the heme iron absorption. However, Cook (1990) reported a nonheme iron absorption varying between 2-20% and a heme iron absorption of 20-46%. So the Monsen model is still a suitable model for estimating the intake of available iron.

That meat (heme iron) is important in decreasing the prevalence of nutritional iron deficiency has been shown in many studies. Alexander et al. (1994) reported that female vegetarians had lower ferritin concentrations than omnivores. Rahmanifar and Bond (1989) showed in their study that the more affluent women in Iran, who consumed a diet with higher quantities of meat and poultry, had a lower incidence of anaemia and iron deficiency than women in low income groups. Walter et al. (1993) reported that schoolchildren in Chile who received heme-fortified cookies over 3 years showed an improved iron status compared to the control group receiving nonfortified wheat cookies.

On the other hand, heme iron may also contribute to an undesirable increase in body stores in iron-repleted individuals (Cook, 1990). Bezwoda et al. (1983) reported that nonheme iron absorption decreased from 18% to 6% with increasing nonheme iron content of the meal, so that the total amount of absorbed iron remained constant. In contrast, the heme iron absorption was about 20%, independent from the heme iron content of the meal. The absolute heme iron absorption increased linearly with the heme iron content of the meal. Cook (1990) confirmed these results and concluded that the adaptive response to variations in heme iron intake is minor compared to nonheme iron intake. Different studies indicated that there might be a relation between high body iron stores and risk of myocardial infarction and cancer in men (Stevens et al., 1988; Salonen et al., 1992). Aschererio et al. (1994) showed in their study that intake of heme iron was correlated positively with myocardial infarction in men. However, the association between heme iron intake and risk of myocardial infarction was limited to men who were not taking multiple vitamin supplements (for example vitamin E) and was considerably worse in diabetics. The authors suggested that iron may adversely affect coronary risk only in the presence of oxidative stress from other sources.

Table 3. Iron, heme iron, nonheme iron and zinc intake[a] provided by the average daily meat consumption (Swiss Meat Board, 1995) in Switzerland in the year 1995

Meat cuts	Meatconsumption g/d	Iron Intake mg/d	Heme iron Intake mg/d	Nonheme iron Intake mg/d	Zinc Intake mg/d
Pork	53	0.5	0.3	0.2	1.9
Beef	30	0.5	0.4	0.1	1.6
Chicken	13	0.1	<0.1	<0.1	0.1
Veal	9	<0.1	<0.1	0.0	0.2
Sum	105	1.1	0.8	0.3	3.8
German Recommendations (1995)[b]		Men: 10 (11%) Women: 15 (7%)			Men:15 (25%) Women:12 (32%)
			intake of available iron and zinc[c]		
		0.1-0.3			0.8-1.4
Requirement for absorbed iron or zinc[d]		Men: 1.0 (10-30%) Women: 1.5 (7-20%)			Men: 2.5 (32-56%) Women: 2.5 (32-56%)

[a]For calculating the average trace element intake, the mean of the two median values for each animal species (beef, pork and chicken) was used.
[b]In parentheses the covering of the recommendations given by the German Nutrition Society (1995) for daily iron and zinc intake expressed as percentage is shown.
[c]The intake of available iron was estimated according to the modified Monsen model (Carpenter and Mahoney, 1992; Monsen et al., 1978) and for calculating the intake of available zinc, the absorption data obtained from different radioisotope studies, carried out by Gallaher et al. (1988) and Sandström and Cederblad (1980) were used.
[d]Data about the daily requirement for absorbed iron and zinc were obtained from King and Turnlund (1989) and Carpenter and Mahoney (1992), respectively. In parentheses the covering of the requirement for absorbed iron and zinc expressed as percentage is shown.

Intake of available zinc

As shown in Table 3, meat is also an important zinc supplier in Switzerland. With an average daily meat consumption of 105 g the recommendations given by the German Nutrition Society (1995) for daily zinc intake were met to 25% (men) and 32% (women). Considering a zinc absorption efficiency from meat of about 20-36%, the contribution of meat to zinc supply was even higher (32-56%). Our results agree with other studies reporting that meat is the most important zinc supplier in many industrialized countries (Hazell, 1982; Sandstead et al., 1990; van Dokkum, 1995).

However, the estimation of available zinc intake established by the absorption data obtained from different studies (Sandström and Cederblad, 1980; Gallaher et al., 1988) does not consider that the zinc absorption is negatively correlated with the zinc content

of a meal (Sandström, 1989). In addition, there is great individual variation in zinc absorption (Sandström and Cederblad, 1980; Gallaher et al., 1988). In several studies it was shown that the body disposes of efficient mechanisms like changes in absorption and gastrointestinal excretion to maintain zinc homeostasis (Kirchgeßner et al., 1990; Sandström, 1991). Also, dietary inhibitors like phytate inhibit zinc absorption (Sandström, 1989). However, Kirchgeßner et al. (1990) and Sandström (1991) stated that animal proteins can improve zinc absorption from a meal containing phytate. Therefore, considering an average zinc availability from meat in the range of 20-36% might be justified.

At present it is not possible to estimate the number of people in industrial countries suffering from mild zinc deficiency syndromes (Aggett and Comerford, 1995). The main reason is that no single reliable indicator exists to assess the zinc status (El-Khoury, 1991; Aggett and Comerford, 1995). Plasma zinc, the most commonly used index of zinc status is affected by circadian variation, meals, stress and other factors that make any interpretation difficult (Sandstead, 1995). Features of zinc deficiency like reduced growth rate in children and infants and impaired immune function have been reported from disadvantaged socio-economic groups in France and USA (Aggett and Comerford, 1995).

There are some findings suggesting that zinc and iron supply are often associated. People at risk of iron and also of zinc deficiency are those who consume cereal based diets, with a high phytate content and little or no meat (Sandstead, 1995). Vulnerable people are infants, young children, premenopausal women and pregnant women. Sandstead et al. (1991) showed in their study with 32 premenopausal women that a serum ferritin level < 20 ng/ml was associated with lower plasma zinc levels compared to women with serum ferritin levels > 20 ng/ml. In a subsequent study of Yokoi et al. (1994), frequent red meat intake of premenopausal women was associated with a higher serum ferritin concentration and a normal plasma zinc disappearance. They concluded that avoidance of red meat increases the risk of iron and zinc deficiencies.

An epidemiological study carried out in Switzerland (1992/93) showed that 31% of the male compared to 19% of the female participants consumed meat every day (Eichholzer et al., 1995). Also, more men (30%) than women (21%) preferred red meat (beef and pork). Jacob Sempach (1995) investigated the nutrient intake of 213 women aged 25-35

years with place of residence in Zurich: 20% of these women did not eat meat at all or only once a month. The results of these studies suggest that men consume more meat than women. From the view of trace element supply, quite the opposite is desirable.

In conclusion, even a relative small amount of meat as consumed in Switzerland is an important source of available iron and zinc. Since the knowledge of the heme iron content in different meat cuts is important for people at risk of iron deficiency and for people at risk of iron overload, data about the heme iron content should be included in food composition tables.

6. Animal Species and Muscle Related Differences in Thiamin and Riboflavin Contents of Swiss Meat

Based on:

Monika Leonhardt and Caspar Wenk **1996**

Food Chemistry (accepted)

ABSTRACT

Animal species and muscle related differences in thiamin and riboflavin contents were studied in pork, chicken, veal and beef. Pork was the best thiamin source and there was no significant difference in thiamin content of longissimus dorsi and shoulder muscles. Also, no difference in thiamin 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/d), thiamin and riboflavin intakes were approximately 0.5 mg/d and 0.2 mg/d, respectively. Recommendation for daily thiamin intake was met to 25% (men) and to 29% (women). Pork itself had a contribution of about 23% (men) and 27% (women). Recommendation for riboflavin intake was met to 10% (men) and 11% (women).

INTRODUCTION

Meat, especially pork, has long been recognized as a good source of B-vitamins (Briggs and Schweigert, 1990). Pork for example is rich in thiamin (vitamin B_1) and contains much more of this vitamin than 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 the thiamin content (Bässler et al., 1992; Souci et al., 1994). In many studies (Miller et al., 1943, Pence et al., 1945; Moss et al., 1983; Ono et al., 1986; Dawson et al., 1988; Hägg and Kumpulainen, 1994), the thiamin and riboflavin contents of meat have been examined. However, only few new data are available. Since animal breeds and feeding practice were modified over the past years, it is also possible that the nutrient contents in meat have changed. Additionally, information about muscle related differences in thiamin and riboflavin content are limited. In most studies, meat samples were directly selected at the abattoir. Since thiamin and riboflavin are water-soluble vitamins, they can be lost with the meat broth (Bässler et al., 1992). In addition, it has to be considered that thiamin is relatively unstable in meat (Bognar et al., 1993; Combs, 1992). One reason is the relatively high pH value of meat (≥5.5). Another reason is that the major part of thiamin in meat occurs as thiamin diphosphate, which is more susceptible to destruction than the free thiamin found in foods of plant origin (Bässler et al., 1992; Machlin, 1991). Also, meat contains heme proteins such as hemoglobin and myoglobin that exhibit antithiamin activity (Gregory, 1985). These factors may greatly affect the vitamin amount available to the consumer. Therefore, it is important to gather further informations about the vitamin contents in meat sold at the retail level.

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

MATERIALS AND METHODS

Samples

The following meat cuts were purchased from different supermarkets and butcher's 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 and for chicken samples, 16 fresh and 9 frozen birds were chosen. The frozen whole birds were thawed overnight in a refrigerator (4° C) and then prepared for analyse. 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 0.2 M and 10 ml 0.1 M sulfuric acid. The homogenates were stored at -20° C until analyses (further details in chapter 5).

Chemical analyses

The thiamin content was determined by the method of Rettenmaier et al. (1979) and the riboflavin content by a modified HPLC method of Schüep and Steiner (1989). In these methods, thiamin and its esters of phosphoric acid and riboflavin and its coenzyme forms (FMN and FAD) were extracted from the samples in an autoclave with diluted sulfuric acid. Esters were hydrolyzed with enzymes. The solutions were adjusted to volume with deionized water and filtered through a paper filter.

For the thiamin determination, a part of the filtrate obtained was purified by ion-exchange chromatography. Thiamin was oxidized to thiochrome, which was extracted with isobutanol. The fluorescence of thiochrome was measured against a blank. The thiamin content was calculated with a standard curve as thiamin chloride hydrochloride.

The riboflavin content was determined by HPLC on a reversed phase column with fluorimetric detection. Unlike the method by Schüep and Steiner (1989), the filtrate obtained was directly injected without the methanol-treatment and the dilution step. The riboflavin concentration was calculated using external riboflavin 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 thiamin or riboflavin content of different meat cuts, the analysis of variance (ANOVA) was computed by using Statgraphics 5.0. Significance of means was determined using Bonferroni's Multiple Range Test. The Mann-Whithney U test was employed to determine differences between thawed and fresh chicken samples.

RESULTS

Table 4 shows the thiamin and riboflavin contents of the meat cuts examined. The thiamin content varied depending on the animal species. Pork was the only meat rich in thiamin, while the meat cuts of the other species were relatively poor in this vitamin. There was no statistically significant difference in the thiamin content between pork longissimus dorsi muscle and pork shoulder muscles (Table 4), or between chicken breast and thigh.

The riboflavin contents in pork and veal longissimus dorsi muscles were significantly higher than that of beef ($P<0.05$). However, muscle related differences of one animal species (pork and chicken) were higher compared to animal species related differences (Table 4). The riboflavin content in shoulder muscles (pork) was nearly twice as high as that of longissimus dorsi. Also, chicken thigh had a higher riboflavin concentration compared to chicken breast ($P<0.05$).

In Fig. 2 the thiamin and riboflavin content of fresh and thawed breast and thigh samples are shown. The thiamin content of the thawed chicken breast samples was significant lower than that of fresh samples ($P<0.01$). There was no difference in the thiamin content of chicken thigh. Also, the riboflavin content in thawed and fresh chicken breast and thigh samples did not significantly differ.

Table 4. Thiamin and riboflavin contents of the examined meat cuts

Meat	Thiamin[c]			Riboflavin		
	Mean ± SD	Median	Range	Mean ± SD	Median	Range
	mg/100 g wet wt			mg/100 g wet wt		
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[ab]	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

n=25, with the exception of chicken (only fresh samples): n=16.
SD, Standard deviation; L.d.m., Longissimus dorsi muscle.
[a,b,c,d] Thiamin and riboflavin contents (means) of the meat cuts with unlike letters were significantly different ($P<0.05$).
[c] Thiamin chloride hydrochloride.

In Table 5 the thiamin and riboflavin intake provided by the average daily meat consumption in Switzerland in the year 1995 is shown. For calculating the thiamin and riboflavin intake, the mean of the two median values for pork and chicken was used. With a daily meat consumption of 105 g, the thiamin intake was about 0.47 mg/day and the riboflavin intake about 0.21 mg/day. Recommendations for the daily thiamin intake were met to 25% (men) and 29% (women) and for riboflavin to 10% (men) and 11% (women).

DISCUSSION

A comparison of our thiamin values with the literature data is difficult, because we calculated the thiamin content as thiamin chloride hydrochloride as described in the method from Rettenmaier et al. (1979). In many food composition tables it is not obvious, if thiamin is expressed as unbound thiamin, thiamin hydrochloride (McCance and Widdowson, 1991) or thiamin chloride hydrochloride. In our study, the average thiamin content in pork was 0.8 mg/100 g wet weight (wet wt). Comparable values in the range of 0.8-0.9 mg/100 g wet wt are described in the literature (Moss et al., 1983;

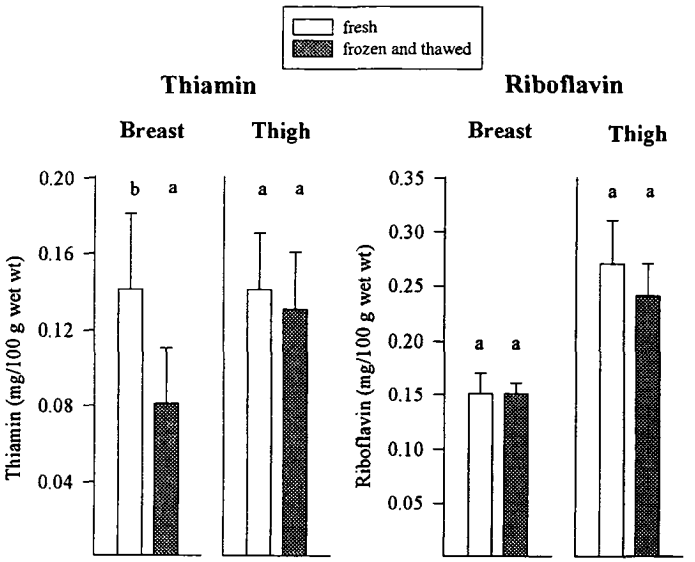

Fig. 2. Thiamin and riboflavin content of fresh (n=16) and frozen and thawed (n=9) chicken breast and thigh samples. Values with unlike letters were significantly different ($P<0.01$).

Bodwell and Anderson, 1986; Dawson et al., 1988; McCance and Widdowson, 1991; Souci et al., 1994; Elmadfa et al., 1996). However, Hägg and Kumpulainen (1994) reported a higher thiamin content for pork (1.1 mg/100 g wet wt). Compared to our values, thiamin contents published are higher for beef and veal, and lower for chicken (Bodwell and Anderson, 1986; Dawson et al., 1988; McCance and Widdowson, 1991; Souci et al., 1994; Elmadfa et al., 1996). In our study, no significant muscle related differences in thiamin content of one species (pork and chicken) were found (Table 4). On the contrary, Miller et al. (1943), Pence et al. (1945) and Moss et al. (1983) found significantly higher thiamin contents in pork loin muscles compared to shoulder muscles. Our values for loin chop (longissimus dorsi muscle) and shoulder muscles (Table 4) are

similar to the values of Moss et al. (1983). However, in our study the variation of the thiamin values of one muscle group was greater than between two meat cuts.

Table 5. Thiamin and riboflavin intake provided by the average daily meat consumption in Switzerland in the year 1995

Meat	Meat consumption[a]	Thiamin[b]		Riboflavin	
		Content[c]	Intake	Content[c]	Intake
	g/d	mg/100 g wet wt	mg/d	mg/100 g wet wt	mg/d
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]			m:1.9 (25%) w:1.6 (29%)		m:2.1 (10%) w:1.9 (11%)

[a] Calculation based on the statistical per capita meat consumption in Switzerland (Swiss Meat Board, 1995).
[b] Thiamin chloride hydrochloride.
[c] For calculating the average thiamin and riboflavin contents of 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 recommendations for daily thiamin and riboflavin intake given by the German Nutrition Society (1995) consider preparation losses of 30% and 10%, respectively. In parentheses is the percentage of the recommendations fulfilled.

The muscle 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/100 g wet wt) compared to loin chops (0.24 mg/100 g wet wt). However, their riboflavin content in loin chops was higher than our value (0.16 mg/100 g wet wt). Also, chicken thigh had a higher riboflavin content compared to breast. This is in agreement with many food composition tables (Bodwell and Anderson, 1986; McCance and 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.

Remarkable is the great variation of the thiamin contents compared to the riboflavin contents. The coefficient of variation for the thiamin values ranged between 21 and 44% and for the riboflavin contents between 11 and 19% . One explanation for the different variability of the thiamin and riboflavin contents might be that thiamin is the more vulnerable vitamin in comparison to riboflavin and therefore vitamin losses can occur to a higher degree during the marketing process. For example, it is well known that thiamin is lost with the meat broth. Consequently we found significantly lower ($P < 0.01$) thiamin contents of thawed chicken breast compared to fresh one (Fig. 2). However, no difference was found in the thiamin content of thawed and fresh chicken thigh. Also, the riboflavin contents of thawed and fresh chicken samples were the same. These results indicate that thiamin losses during frozen storage and thawing might differ, depending on the muscles examined. Bognár (1995) reported that only small thiamin and riboflavin losses occur during frozen storage. Fennema (1975, 1982) reported changes in animal tissues thiamin and riboflavin contents during the entire freezing process in the range of +34 to -42% for thiamin and in the range of +44 to -43% for riboflavin. A release of thiamin and riboflavin from precursor substances is a possible explanation for the increase of these vitamin contents (Bognár, 1995).

Another explanation for the great thiamin variability might be the vitamin content of animal feeds. In general, the feed composition has only little influence on the amount of water-soluble vitamins in meat, except for niacin and thiamin (Kühne, 1982). Different studies indicated that pigs can store sufficient amounts of thiamin to meet the requirement on a thiamin-deficient diet for as long as two months (Oltjen and Dinius, 1975). Miller et al. (1943) showed that by feeding a ration supplemented with thiamin, the thiamin content of pork loin increased up to 2.31 ± 0.10 mg/100 g wet wt compared to 0.95 ± 0.04 mg/100 g wet wt of the control group. In a follow up study, it was shown that with a thiamin supplementation of 50 mg/day, the pig muscle tissue was saturated within 35 days (Pence et al., 1945). We also showed (unpublished results) that the thiamin content of longissimus dorsi muscle was relatively high (1.48 ± 0.07 mg/100 g wet wt) in pigs (n=9) receiving a diet, which contained a component rich in thiamin (10% sunflower meal). Since thiamin is not supplemented in the pig feeds used in Switzerland, its different natural occurring content might be responsible for the great variation.

Table 5 shows the thiamin and riboflavin intake provided by the average meat consumption. The average meat consumption contributed to meet the recommendation for daily

thiamin intake, given by the German Nutrition Society (1995), to 25% (men) and to 29% (women). Pork itself had a contribution of about 23% (men) and 27% (women). The recommendation for daily thiamin intake (German Nutrition Society, 1995) considers preparation losses of about 30%. This value might be slightly underestimated, because especially during processes like stewing and cooking of the meat, losses range between 40-70% (Sommers and Hagen, 1981; Burger, 1982; Seuss et al., 1988; McCance and Widdowson, 1991). However, thiamin destruction in the range of 0-42% (Sommers and Hagen, 1981; Burger, 1982; Seuss et al., 1988; McCance and Widdowson, 1991, Rhee et al., 1993) is reported for processes like frying and grilling, and during microwave heating only small thiamin losses in the range of 4-14% occurred (Uherová et al., 1993). Average losses of 30% might be justified regarding the application of different preparation techniques.

The contribution of the average meat consumption in Switzerland to fulfill the recommendation for the 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. The recommended daily riboflavin intake (German Nutrition Society, 1995) considers preparation losses of about 20%. Since riboflavin is much more heat stable compared to thiamin, this value might be suitable.

In conclusion, pork was a very good thiamin source, while the other meat cuts were unimportant as thiamin suppliers. The riboflavin content was dependent from the muscles examined. Pork shoulder muscles had higher concentrations compared to pork longissimus dorsi muscle and the riboflavin content of chicken thigh was higher than that of chicken breast. Remarkable is the great variation in thiamin content. Further studies are needed to examine if this was due to losses during the marketing process or to different thiamin contents of the animal feeds. A thiamin supplementation of the pig diet might be useful to further increase its content in pork.

7. Vitamin E Content of Animal Products: Influence of Animal Nutrition

Based on:

Monika Leonhardt, Stefan Gebert and Caspar Wenk **1996**

Zeitschrift für Ernährungswissenschaft (accepted)

ABSTRACT

The α-tocopherol content of different meat cuts was examined. Chicken thigh had the highest vitamin E content, followed by chicken breast and pork shoulder ($P<0.05$). The lowest concentrations were found in longissimus dorsi muscle from pork, beef, veal and in beef shoulder. Considering the average daily lean meat consumption (105 g) in Switzerland, recommendation for daily vitamin E intake was met to 3%.

Supplementation of 200 mg α-tocopherol acetate/kg feed to pigs and laying hens significantly increased the α-tocopherol content in all examined products. The α-tocopherol accumulation differed according to the following ranking: egg yolk > liver > adipose tissue > longissimus dorsi muscle. The α-tocopherol:energy ratios were 28.8, 7.3, 0.9 and 1.2 mg/MJ for egg yolk, liver, adipose tissue and longissimus dorsi muscle of the vitamin E supplemented groups, respectively. The results showed that meat, with the exception of chicken thigh, is not an important supplier of vitamin E, even from animals fed a vitamin E enriched diet. Egg yolk became a good source of vitamin E for human nutrition by dietary modification.

INTRODUCTION

The main function of vitamin E (α-tocopherol) is to protect susceptible cellular structures, especially polyunsaturated fatty acids in cell membranes, against damage from oxygen-free radicals. Foods rich in vitamin E are those from plant origin like seed oils, vegetables and whole grains. Most animal products are poor sources of this vitamin (Meydani, 1995). However, feeding practices have changed in the past years and vitamin E supplementation of animal diets has garnered interest. Many studies (Arnold et al., 1993; Asghar et al., 1991b, King et al., 1995) show that supplemental dietary vitamin E improves meat quality by reducing lipid oxidation and enhancing color stability. It is also well known that vitamin E deposits in certain animal tissues. Regarding human nutrition, limited information exists about the vitamin E supply of products from supplemented animals.

The objective of the present study was to examine the α-tocopherol content of lean meat available in Switzerland. We also studied the efficacy of the same dietary vitamin E supplementation to pigs and laying hens in order to increase the α-tocopherol content of the respective animal products and their vitamin E supply for human nutrition.

MATERIALS AND METHODS

Comparison of different meat cuts

The following meat cuts were purchased from different supermarkets and butcher's shops in Zurich (Switzerland): pork (chop and shoulder), beef (prime rib and shoulder), chicken (breast and thigh) and veal (chop). Sample size of every meat cut was 25 pieces. The meat cuts were transported to our laboratory, where the longissimus dorsi muscle (l.d.m.) 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 pieces. The samples were stored at -20° C until the analytical procedure was performed (further details in chapter 5).

Trial with pigs

Twelve growing pigs (castrates) were divided into two groups of six. The animals were fed a basal diet based on barley (35%), maize (30%), soybean meal (10%) and sunflower meal (10%). The remaining ingredients were potato protein, animal fat, lysine, minerals and vitamins. The diet of the control group was not enriched with α-tocopherol and the diet of the vitamin E group was supplemented with 200 mg α-tocopherol acetate/kg feed. The analyzed α-tocopherol concentrations in the diets were 15 mg/kg and 258 mg/kg feed for the control and vitamin E group, respectively. Water and feed were given ad libitum. The pigs were fattened from 25 kg to 105 kg body weight. The animals were slaughtered in a local abattoir. The liver was immediately removed and cooled. At 24 hr postmortem, chops (l.d.m.) and adipose tissue samples were obtained.

Trial with laying hens

Ten laying hens were divided into two groups of five and fed either a basal diet or the basal diet supplemented with 200 mg α-tocopherol acetate/kg feed. The basal diet was composed of wheat (30%), maize (30%), soybean meal (15%) and sunflower meal (10%). The remaining ingredients were animal fat, lysine, methionine, minerals and vitamins. The analyzed α-tocopherol concentrations in the diets were 15 mg/kg feed for the control and 213 mg/kg feed for the vitamin E group. Water and feed were given ad libitum. After the diets were fed for four weeks, one egg of every hen was collected and stored at 4° C until analysis.

Chemical analysis, calculation and statistical methods

The α-tocopherol content was determined by the method of Rettenmaier and Schüep (1992). For calculating the vitamin E:energy ratio (mg/MJ) of the different samples, the median and the energy values of Souci et al. (1989; 1994) were used. The vitamin E allowances recommended (women: 1.4 mg/ MJ, men: 1.2 mg/MJ) do not consider preparation losses, whereas the recommendation for daily vitamin E intake (13 mg/day) takes into account preparation losses of 10% (German Nutrition Society, 1995).

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 α-tocopherol content of different meat cuts, the analysis of variance (ANOVA) was computed by 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 in the α-tocopherol content of animal products between the control and the vitamin E groups.

RESULTS AND DISCUSSION

In Table 6 the α-tocopherol content and α-tocopherol:energy ratio (mg/MJ) of different meat cuts available in Switzerland, are shown. Chicken thigh was the meat cut with the highest α-tocopherol content, followed by chicken breast and pork shoulder muscles ($P<0.05$). Our findings for the vitamin E content of chicken were higher than the values of McCance and Widdowson (1991), Souci et al. (1989) and Elmadfa et al. (1996). One explanation for this might be that the diets of broilers in Switzerland are now very often supplemented with vitamin E (Pfirter, 1996, personal communication). This may account for the relative high α-tocopherol content found in chicken meat, especially in chicken thigh. The lowest vitamin E concentrations were found in pork (l.d.m.), beef (l.d.m. and shoulder muscles) and veal (l.d.m.) and no statistical significant difference was found in the α-tocopherol content of these meat cuts. McCance and Widdowson (1991) published lower vitamin E concentrations for lean pork and beef (0 mg and 0.15 mg/100 g, respectively). In relation to our values, data from Souci et al. (1994) and Elmadfa et al. (1996) showed comparable vitamin E concentrations in pork (0.37 and 0.30 mg/100 g) and higher contents of beef (0.48 and 0.5 mg/100 g). Also, the published vitamin E content of veal chop by Elmadfa et al. (1996) was higher (0.6 mg/100 g chop) than our value. Similarly, an explanation for the variability in the reported vitamin E contents might be different vitamin E contents of animal diets (Bässler et al., 1992).

Lean meat was not an important vitamin E supplier in the nutrition of the Swiss. The vitamin E intake provided with the average daily lean meat consumption in Switzerland was 0.41 mg (Table 6). This vitamin E intake covered 3% of the recommendation for the

daily vitamin E intake given by the German Nutrition Society (1995). Only chicken thigh with its relatively high vitamin E:energy ratio (2.5 mg/MJ) was a good vitamin E supplier for human nutrition.

Table 6. α-Tocopherol content and α-tocopherol:energy ratio (mg/MJ) of different meat cuts and α-tocopherol intake provided by the average daily meat consumption in Switzerland (1995)

Meat cuts	α–Tocopherol				Meat consumption	α-Tocopherol intake
	Mean ± SD	Median	Content[d]	Ratio[e]		
		mg/100 g		mg/MJ	g/day	mg/day
Pork			0.35		53	0.19
L.d.m.	0.27 ± 0.10[a]	0.26		0.6		
Shoulder	0.52 ± 0.23[b]	0.44		1.0		
Beef			0.22		30	0.07
L.d.m.	0.26 ± 0.16[a]	0.21		0.5		
Shoulder	0.26 ± 0.16[a]	0.22		0.5		
Veal (L.d.m.)	0.29 ± 0.11[a]	0.30	0.30	0.8	9	0.03
Chicken			0.89		13	0.12
Breast	0.62 ± 0.22[b]	0.64		1.4		
Thigh	1.20 ± 0.53[c]	1.14		2.5		
Sum					105	0.41
German[f]			Men:	1.2	Men:	13 (3%)
Recommendations (1995)			Women	1.4	Women:	13 (3%)

n=25; SD, Standard deviation; MJ, Megajoule; L.d.m., Longissimus dorsi muscle.
[a,b,c]α-Tocopherol contents (means) with unlike letters were significantly different (P<0.05).
[d]For calculating the average α-tocopherol content of each animal species (pork, beef and chicken), the mean of the two median values was used.
[e]For calculating the α-tocopherol:energy ratio (mg/MJ) the median value and the energy values in Souci et al. (1989; 1994) were considered.
[f]In parentheses the covering of the recommendations expressed as percentage is shown.

In Table 7, the α-tocopherol contents of longissimus dorsi muscle, adipose tissue and liver of the control and vitamin E groups are shown. Dietary vitamin E supplementation to pigs resulted in a significant increase of the α-tocopherol content of l.d.m. (P<0.05), adipose tissue and liver (P<0.01). Also, the study with laying hens showed that a vitamin E supplementation significantly increased the α-tocopherol content of eggs (yolk), compared to the control group (P<0.05). Although, in both trials (pigs and laying hens) the diets were supplemented with 200 mg α-tocopherol acetate/kg feed, the α-tocopherol accumulation differed among the examined animal products according to the following ranking: egg yolk > liver > adipose tissue > longissimus dorsi muscle. Compared to the

control groups, the α-tocopherol content of egg yolk, liver, adipose tissue and pork l.d.m. of the vitamin E groups were fifteenfold, sevenfold, threefold and twice as high, respectively. Meat (l.d.m.) and adipose tissue of the vitamin E group were bad vitamin E suppliers. The vitamin E:energy ratios for these samples were 1.2 and 0.9 mg/MJ, respectively. The increase of the α-tocopherol content of liver by the vitamin E supplementation was important for human nutrition. Considering an energy value of 549 kilojoules/100 g (Souci et al., 1994) the vitamin E:energy ratio of the liver samples of the vitamin E group increased to 7.3 mg/MJ. However, pig liver is consumed only in very low quantities and a high consumption is not favorable for different reasons. Remarkable is the observation, that the l.d.m. α-tocopherol content of the control group was comparable to those of pork chop samples (l.d.m.) at the retail level. Therefore it can be concluded that the diets of pigs in Switzerland were not supplemented with significant quantities of vitamin E.

Table 7. α-Tocopherol content and α-tocopherol:energy ratio (mg/MJ) of different products from animals fed a control or a vitamin E supplemented diet

	α-Tocopherol		
	Mean ± SD	Median	Ratio[a]
	mg/100 g		mg/MJ
Pigs (n=6)			
L.d.m. (control)	0.24 ± 0.09	0.22	0.5
L.d.m (vitamin E)	0.51 ± 0.21*	0.52	1.2
Adipose tissue (control)	0.99 ± 0.13	1.00	0.3
Adipose tissue (vitamin E)	2.92 ± 0.31**	2.95	0.9
Liver (control)	0.58 ± 0.05	0.60	1.1
Liver (vitamin E)	4.10 ± 0.51**	4.00	7.3
Laying hens (n=5)			
Egg yolk (control)	3.04 ± 0.29	3.00	2.1
Egg yolk (vitamin E)	45.27 ± 6.40*	42.05	28.8

*, P<0.05; **, P<0.01.
SD, Standard deviation; MJ, Megajoule; L.d.m., Longissimus dorsi muscle.
[a]For calculating the α-tocopherol:energy ratio (mg/MJ) the median value and the energy values in Souci et al. (1994) were considered. Allowance for vitamin E are: 1.2 mg/MJ for men and 1.4 mg/MJ for women (German Nutrition Society, 1995).

Many studies have investigated the effect of a vitamin E supplementation of animal diets on the meat α-tocopherol content. Vogg (1991), Asghar et al. (1991b) and Monahan et

al. (1992) fed pigs different levels of vitamin E. The highest l.d.m. α-tocopherol value (8.0±0.4 μg/g) was reported by Monahan et al. (1992). In their study pigs received a dietary vitamin E supplementation of 200 mg α-tocopherol acetate/kg feed. Arnold et al. (1992), Arnold et al. (1993) and Liu et al. (1994) fed steers α-tocopherol acetate enriched diets. Arnold et al. (1993) reported that the group of steers receiving 2000 mg vitamin E/day had a α-tocopherol content of 0.82 mg/100g in gluteus medius and 0.67 mg/100g in longissimus lumborum. Engeseth et al. (1993) showed that 500 mg vitamin E/day given to veal calves for 12 weeks after birth resulted in increased α-tocopherol concentration in l.d.m. (0.61 mg/100 g). These studies show that meat from supplemented animals is not a good vitamin E source. Liu et al. (1994) calculated that even an exclusive beef consumption in the USA (84 g/day) from supplemented animals would only provide 0.56 mg vitamin E/day. However, chicken meat, especially chicken thigh, is possibly an exception. Lin et al. (1989) and King et al. (1995) used 100 mg and 150 mg of vitamin E/kg broiler feed, respectively. The resulting α-tocopherol contents of chicken thigh were 1.0 mg/100 g and 1.3 mg/100 g, respectively. Nepp et al. (1996) tested the compatibility of a high vitamin E supplementation in broilers. They enriched diets of broilers with 0, 100, 1000, 10000, 20000 mg α-tocopherol acetate/kg feed. The resulting α-tocopherol contents of chicken thigh were 0.11, 0.49, 3.18, 9.05 and 12.16 mg/100 g, respectively. It should be noted, that these high vitamin E supplementations (>100 mg/kg feed) are economically not useful.

By dietary vitamin E supplementation of laying hen diets, egg yolk became a good vitamin E source (28.8 mg vitamin E/MJ). This is in agreement with many other studies. Garwin et al. (1992) and Jiang et al. (1994) supplemented the feed with 200 mg vitamin E/kg. The α-tocopherol concentrations in egg yolk were 18.8 mg/100 g and 24.6 mg/100 g egg yolk, respectively. Although, in our study the laying hens also received 200 mg α-tocopherol acetate/kg feed, the α-tocopherol concentration in egg yolk (45.3 mg/100 g) was much higher compared to the study of Garwin et al. (1992) and Jiang et al. (1994). One reason might be that we collected the eggs after a feeding period of 28 days, whereas Jiang et al. (1994) collected the eggs after 21 days. Surai and Ionov (1992) showed in their study that supplementing laying hens with vitamin E, caused an increase of the egg yolk α-tocopherol concentration to a maximum level and than the α-tocopherol content decreased again and stabilized at a lower level. They supplemented laying

hens with 10, 100, 1000 and 10000 mg vitamin E/kg feed for 60 days. The maximum egg yolk α-tocopherol content of the group receiving 10000 mg/kg was found after three weeks (1025 mg/100 g). Then the α-tocopherol concentration decreased again and stabilized at a level of 370 mg/100 g. The maximum egg yolk α-tocopherol levels of the groups receiving 100 mg/kg and 1000 mg/kg (54.0 mg/100 g and 363 mg/100 g) were detected later and were lower compared to the group with the highest vitamin E level. Therefore, in further studies it should be examined, after how many days of feeding supplemental vitamin E, the α-tocopherol concentration in egg yolk remains stable.

In conclusion, lean meat is generally not an important vitamin E supplier in human nutrition, not even from supplemented animals. One exception might be chicken meat, especially chicken thigh. A dietary vitamin E supplementation to laying hens resulted in an increase of vitamin E concentration in egg yolk, so that egg yolks from these laying hens were potent vitamin E suppliers for human nutrition.

8. Variability of Selected Vitamins and Trace Elements of Different Meat Cuts

Based on:

Monika Leonhardt and Caspar Wenk

Journal of Food Composition and Analysis (submitted, June **1996**)

ABSTRACT

The iron, heme iron, zinc, thiamin, riboflavin and α-tocopherol content of different meat cuts of pork, beef, veal and chicken, available at the retail level, were analyzed. The highest coefficients of variation were calculated for α-tocopherol (CV: 35-62%) and the lowest for riboflavin (CV: 11-19%) and zinc (CV: 8-17%). The coefficients of variation for veal iron and heme iron contents were relatively high compared to those of the other meat cuts and may be a result of different veal production systems. In conclusion, the coefficients of variation are higher for those nutrients in meat, which are affected by the feed composition, compared to those mainly genetically determined.

INTRODUCTION

In industrialized countries, meat provides significant amounts of nutrients (Erbersdobler, 1994). As shown previously, even a relatively small amount of meat (especially beef and pork shoulder) as is consumed in Switzerland, was an important source of available iron and zinc (Leonhardt and Wenk, 1996a). Pork was also rich in thiamin and pork shoulder and chicken thigh had high amounts of riboflavin (Leonhardt and Wenk, 1996b), whereas the α-tocopherol content of meat was low (Leonhardt et al., 1996). In many food composition tables, the vitamin and trace element content of meat cuts is described (McCance and Widdowson, 1991; Souci et al., 1994). However, in most cases only one value (mean) is declared. Few data are available about the variability of nutrients (e.g. coefficient of variation) in meat. Also, only limited information exists, if some nutrients in meat vary to a greater extent compared to other nutrients. These data could be helpful for judging the reliability of nutrient consumption data of different population groups.
The objective of the present study was to examine the variablilty of the trace element (total iron, heme iron and zinc) and vitamin (thiamin, riboflavin and α-tocopherol) contents of different meat cuts by calculating their coefficients of variation from the data citied above.

MATERIALS AND METHODS

The following meat cuts were purchased from different supermarkets and butcher's shops in Zurich (Switzerland): pork (chop and shoulder), beef (prime rib and shoulder), chicken (breast and thigh) and veal (chop). Sample size of every meat cut was 25 pieces. From beef prime rib, pork chop and veal chop the longissimus dorsi muscle was separated and the other meat cuts were trimmed of visible fat, skin and connective tissue (further details in chapter 5). In all samples iron, heme iron, zinc, thiamin (vitamin B_1), riboflavin (vitamin B_2) and α-tocopherol (vitamin E) were analyzed. Except in beef shoulder, the thiamin and riboflavin content was not determined. For iron and zinc determination, the lyophilized samples were ashed and cooked subsequently with 25% hydrochloric acid. Iron and zinc were measured with an atomic absorption spectrometer in the Swiss Federal Research Station for Animal Production (RAP, Posieux, Switzerland). Heme

iron was determined by the alkaline haematin method of Karlsson and Lundström (1991). The thiamin content was determined by the method of Rettenmaier et al. (1979) and calculated with a standard curve as thiamin chloride hydrochloride. Analysis of riboflavin content in meat was performed by a modified HPLC method of Schüep and Steiner (1989). Unlike this method, the obtained filtrate was directly injected without the methanol-treatment and the dilution step. The riboflavin concentration was calculated using external riboflavin standards. The α-tocopherol content was determined by the method of Rettenmaier and Schüep (1992).

RESULTS AND DISCUSSION

In Table 8 the nutrient contents (mg/100 g wet weight) and their coefficients of variation are shown. α-Tocopherol was the most variable nutrient (CV: 35-62%). The main reason for this observation might be that incorporation of α-tocopherol in meat is affected by the α-tocopherol content of animal feeds. Many studies (Lin et al., 1989; Monahan et al., 1992; Arnold et al., 1993, Engesethet al., 1993) provide evidence that meat α-tocopherol concentration increases as dietary α-tocopherol increases. In contrast, the feed composition has only little influence on the amount of water-soluble vitamins in meat, except niacin and thiamin (Kühne, 1982). Pence et al. (1945) showed that by feeding pigs a ration supplemented with thiamin (50 mg/day), the thiamin content of pork loin increased up to 2.5 mg/100 g wet weight. Therefore, different thiamin content of animal feeds might be responsible for the high variability of the meat thiamin content. However, since thiamin is a relatively unstable vitamin, it is also possible that the high variability of the thiamin content in meat was due to losses during the marketing process (Leonhardt and Wenk, 1996b). Riboflavin and zinc were the nutrients with the lowest coefficient of variation. The contents of both nutrients are mainly genetically determined and are only slightly influenced by feed composition (Flachowsky and Jahreis, 1995). Also, iron and heme iron content of the meat cuts are not affected by feed composition, except in deficiency as is valid for veal iron and heme iron concentration. Ono et al. (1986) proposed that veal production systems (iron content and bioavailability of the iron in feed) had significant influence on the iron content of veal. Scheeder et al. (1994) later confirmed these results. They also reported that the veal pigment (heme iron) content

was affected by the iron concentration of the feed. Therefore, the high coefficients of variation for iron and heme iron content in veal might be caused by the different feeding regimens of calves in Switzerland.

In conclusion, nutrient contents of meat, such as the α-tocopherol content, that can be affected by animal feed composition showed the highest coefficients of variation, whereas nutrients such as riboflavin and zinc that are only slightly influenced by feed composition had only a low coefficient of variation.

Table 8. Contents (mg/100 g wet wt) and coefficients of variation of selected vitamins and trace elements of the examined meat cuts (n=25)

	Iron			Heme iron			Zinc			α–Tocopherol			Thiamin[a]			Riboflavin		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
	mg/100 g		%	mg/100 g		%	mg/100 g		%	mg/100 g		%	mg/100 g		%	mg/100 g		%
Pork (l.d.m.)	0.49	0.06	12	0.28	0.05	18	1.66	0.22	13	0.27	0.10	37	0.84	0.23	27	0.16	0.02	13
Pork shoulder	1.28	0.32	25	0.82	0.27	33	5.32	0.89	17	0.52	0.23	44	0.70	0.31	44	0.31	0.06	19
Beef (l.d.m.)	1.93	0.52	27	1.17	0.24	21	5.10	0.84	16	0.26	0.16	62	0.04	0.01	25	0.13	0.02	15
Beef shoulder	1.83	0.46	25	1.55	0.33	21	5.79	0.82	14	0.26	0.16	62	-			-		
Veal (l.d.m.)	0.41	0.16	39	0.43	0.18	42	2.48	0.43	17	0.29	0.11	38	0.08	0.03	38	0.19	0.02	11
Chicken breast	0.36	0.05	14	0.15	0.02	13	0.64	0.05	8	0.62	0.22	35	0.12	0.05	42	0.15	0.02	13
Chicken thigh	0.65	0.07	11	0.46	0.06	13	1.61	0.14	9	1.20	0.53	44	0.14	0.03	21	0.26	0.04	15

SD, Standard deviation; CV, Coefficient of variation; l.d.m., longissimus dorsi muscle.
[a] Thiamin chloride hydrochloride.
- not analyzed

9. Stability of α-Tocopherol, Thiamin, Riboflavin and Retinol in Pork Muscle and Liver during Heating as Affected by Dietary Supplementation

Based on:

Monika Leonhardt, Stefan Gebert, and Caspar Wenk **1996**

Journal of Food Science (in press)

ABSTRACT

The α-tocopherol (Vit E) and ascorbic acid (Vit C) supplementation of pig diets increased ($P<0.05$) liver α-tocopherol concentrations. After heating, the liver samples of both treated groups and the longissimus dorsi muscle samples of the vitamin C group showed increased riboflavin retention ($P<0.05$). The supplemented and control groups did not show differences regarding retention of α-tocopherol, retinol and thiamin in heated liver and longissimus dorsi. Dietary vitamin C resulted in higher liver vitamin E and was most effective in protecting riboflavin against loss during heating of liver or longissimus dorsi.

INTRODUCTION

The meat of pigs is an important source of thiamin and riboflavin. Although pig liver is a rich source of retinol and riboflavin, the daily human dietary intake of liver is low. During preparation, especially by heating foods, vitamins may be partially destroyed. Thiamin is very heat-sensitive and up to 85 % can be lost by different processing methods (Combs, 1992). Vitamin E (α-tocopherol) and C (ascorbate) have antioxidative properties. They are used as functional ingredients to protect foods against destructive effects of oxygen (Giese, 1995; Johnson, 1979). Ascorbic acid is an inhibitor of enzymatic browning in some fruits and vegetables (Giese, 1995) and has a protective effect on thiamin, riboflavin, pantothenic acid, biotin, folic acid, tocopherols and retinol (Buddecke, 1984). Ascorbic acid and its fat-soluble esters also prevent oxidation of oils, milk, pork, beef fats and other foods (Cort, 1982).

Postmortem application or antemortem infusion of vitamin C has improved lipid and color stability of meat. Many studies have shown this with different concentrations and methods of administration. Mitsumoto et al. (1991b) brushed a vitamin C solution onto beef. Okayama et al. (1987), Harbers et al. (1981) and Mitsumoto et al. (1991c) dipped beef in ascorbic acid solutions. Mitsumoto et al. (1991a), Shivas et al. (1984), and Benedict et al. (1975) directly added ascorbic acid to ground beef, and Watts and Lehmann (1952) added vitamin C to ground pork. Hood (1975) and Schaefer et al. (1995) infused ascorbic acid into the jugular vein of beef immediately before slaughter. All studies showed that ascorbic acid treatment could retard pigment and lipid oxidation. However, Benedict et al. (1975) reported that vitamin C exerted a definite prooxidant effect. Whether vitamin C acts as an antioxidant or as a prooxidant may depend on the concentration, the presence of metal ions and the meat tocopherol content (Harbers et al., 1981; Schaefer et al., 1995).

Fat-soluble tocopherols protect polyunsaturated fatty acids (PUFAs) from damage by free radicals (Asghar et al., 1991a). One hypothesis stated that by terminating chain reactions among PUFAs in the membranes, not only fats are protected against oxidation but also other cellular components such as oxymyoglobin (Yin et al., 1993). Tocopherols are used as antioxidants in animal fats, baked goods, bacon, lard, margarine, butterfat and various oils (Giese, 1995).

The objective of our study was to determine whether a high supplementation of pig diet with α-tocopherol or ascorbate influenced the amount of vitamins (α-tocopherol, retinol, thiamin and riboflavin) in liver and pork chops (longissimus dorsi muscle). We also examined whether dietary supplementation affects vitamin retention after heating of liver or chops.

MATERIALS AND METHODS

Animal groups and samples

Twelve castrated male piglets were divided into three groups of four. The animals were fed a diet based on barley (35%), maize (30%), soybean meal (10%) and sunflower meal (10%). Remaining ingredients were potato protein, animal fat, lysine, limestone flour, salt and celite. The feed of the control group was not enriched with α-tocopherol or ascorbate. The diet of the vitamin E group was supplemented with 200 mg α-tocopheryl acetate/kg feed. The diet of the vitamin C group was supplemented with 250 mg ascorbate/kg feed. All diets were enriched with a vitamin mix which contained, among other vitamins, riboflavin (4 mg/kg) and retinol (10,000 IU/kg). Thiamin was not supplemented.

Vitamin E concentrations in the diets were 60, 63 and 246 mg/kg feed for the control, the vitamin C, and the vitamin E groups, respectively. Vitamin C contents were 51, 195 and 34 mg/kg feed, respectively.

Water and feed were given *ad libitum*. The pigs were fattened from 25 kg to 105 kg body weight. Three animals of each treatment group were slaughtered in a local abattoir. The liver was immediately removed and cooled. At 24 hr postmortem, seven chops from each carcass (three animals/group) were removed. The fourth animal of each group was slaughtered separately. From these animals only a liver sample (*lobus hepatis dexter lateralis*) was available. The contents of retinol, α-tocopherol, thiamin, riboflavin and dry weight (dry wt) were analyzed in each liver (*lobus hepatis dexter lateralis*, n=4) and chop sample (longissimus dorsi muscle, n=3) of each animal. Muscle tissue is very low in retinol, so it was not analyzed in longissimus dorsi muscle. Vitamin C was also not analyzed, because studies with pigs (Yen, 1984; 1990) and chicken (King et al., 1995)

showed that even with high vitamin C supplementation the tissue vitamin C concentrations only changed marginally.

Method of heating

Liver samples (≡500 g each) were taken from each of the three animals of one group and combined to make 1 sample. The combined sample was cut into small pieces and ground with a laboratory meat grinder into a homogeneous mass. From this mass two samples were taken for duplicate analyses. The rest was distributed onto five aluminum dishes (230-240 g liver/dish) and gradually heated to 150° C with a sigmoid slope of temperature increase. After 45 min the final temperature (150° C) was reached and maintained constant at 150° C to the end of heating. The heating took place over 2 hr 30 min. All samples were then cooled for 1 hr at 4° C, mixed again and prepared for determination of α-tocopherol, retinol, thiamin, riboflavin and dry weight.

Chop samples from each of three animals/group were trimmed of visible fat and bones and the longissimus dorsi muscle was separated. The reunified sample was cut into small pieces and treated the same as liver samples, but in this case the meat was ground twice to provide a good homogenate. Two samples of the homogenate were taken for duplicate analyses. The rest was distributed onto five aluminum dishes (140-150 g/dish), heated the same as the liver samples and analyzed for α-tocopherol, thiamin, riboflavin and dry weight.

Analytical techniques

Analysis of α-tocopherol content in meat as well as α-tocopherol and retinol contents in liver were performed in duplicate by the method of Rettenmaier and Schüep (1992). Thiamin content was measured by the method of Rettenmaier et al. (1979) and riboflavin by a modified method of Schüep and Steiner (1989). The main difference was that the filtrate was directly injected without methanol treatment and the dilution step. To determine the dry weight (wt), 3 g of each sample was dried in triplicate for 4 hr at 104° C to constant weight.

Statistical analysis

Data were treated by analysis of variance (ANOVA) and computed by using Statgraphics 5.0. When significant ($P<0.05$) dependent variable effects were found, means were separated using the Least Significant Difference Test.

RESULTS AND DISCUSSION

Influence of dietary supplementation on vitamin contents in liver and longissimus dorsi muscle

The vitamin contents of the different liver samples were compared (Fig. 3). The liver α-tocopherol content of the vitamin E and C groups was higher ($P<0.05$) than that of the control group. The average liver vitamin E contents were 12.4±1.7 µg/g, 22.0±6.9 µg/g and 31.2±4.9 µg/g wet wt for the control, the vitamin C and the vitamin E groups, respectively. In a study of Vogg (1989) pigs received a diet with 88 mg vitamin E/ kg feed. The liver Vit E content was 12.4±2.3 µg/g wet wt. This value was comparable to the average liver Vit E content of our control group, although the Vit E content of the feed in our study had been lower. Asghar et al. (1991a) fed pigs 100 mg or 200 mg vitamin E/kg feed. The resulting liver Vit E contents were 9.2±0.93 µg/g and 12.6±1.9 µg/g wet wt. The main reason for lower values compared to our results might be that Asghar et al. (1991a, 1991b) isolated Vit E without saponification of samples. In the liver Vit E occurs free or bound to fatty acid (Elmadfa and Leitzmann, 1988). The bound Vit E was presumably not determined by Asghar et al. (1991a, 1991b).

Although the Vit E contents of the control group and the vitamin C group diets were the same, the average liver Vit E content of the Vit C supplemented group was higher than that of the control group. The large standard deviation for the liver Vit E content of the Vit C group was mostly due to one very high value (11 mg/100 g dry wt). Even if we excluded that value, the average liver Vit E value (5.8 ± 1.00 mg/100 g dry wt) of the Vit C group was higher than the average liver Vit E value of the control group (3.98 ± 0.52 mg/100 g dry wt). Many studies have suggested that Vit E and C act synergistically.

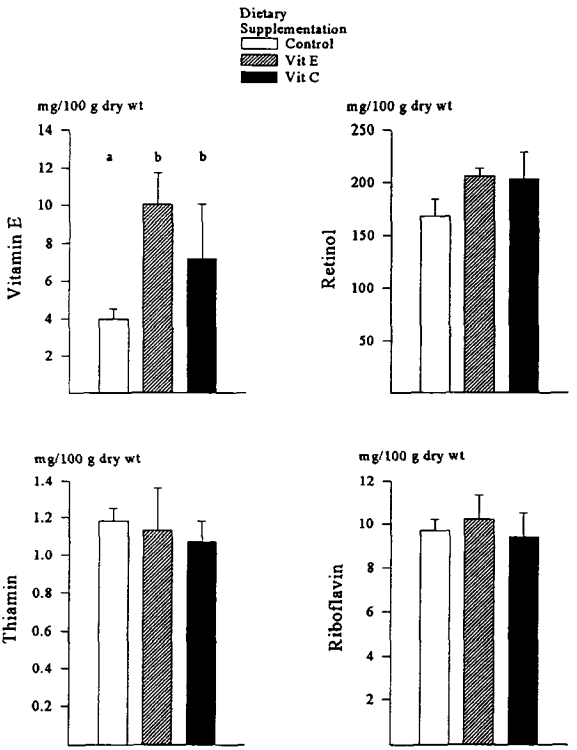

Fig. 3. Influence of α-tocopherol and ascorbate supplementation in pig feed on vitamin concentrations of liver (n=4). Values represent means ± S.D. Means with no common letters differ significantly ($P<0.05$).

Probably Vit E acts as the primary antioxidant by quenching lipid peroxyl radicals. The resulting Vit E radical is then regenerated by Vit C (Doba et al., 1985; Elmadfa and Bosse, 1985; Kläui and Pongracz, 1981; Mitsumoto et al., 1991a; Schaefer et al., 1995; Yin et al., 1993). This is the reasoning for employing vitamin C as an antioxidant in the method for determination of vitamin E and A (Rettenmaier and Schüep, 1992).

The results of *in vivo* studies are conflicting. Chen and Chang (1978) showed that adequate levels of Vit C given to vitamin E-deficient weanling male guinea pigs increased

the plasma Vit E. This was confirmed in a study with Vit E-deficient rats (Chen et al. 1980). However, a high Vit C supplementation to a diet with marginal Vit E levels in guinea pigs lowered the Vit E levels (Chen and Chang, 1979).

The opposite was shown in a study of Yen (1990) with weanling pigs fed a low Vit E and selenium diet. Plasma Vit E was decreased by Vit C supplemented (660 mg/ kg feed) diets with a low Vit E content (0 or 10 mg/kg feed), but increased by Vit C supplementation in those fed 20 mg vitamin E/kg feed. In addition, plasma glutathione peroxidase activity was increased by Vit C supplementation. Combs and Pesti (1976) also reported that chicken feed supplemented with Vit C promoted post-absorptive selenium utilization, resulting in increased activities of the selenium-containing enzyme glutathione peroxidase in plasma. This might also be a factor for the higher liver Vit E content of the Vit C group in comparison to the control group, because selenium reduces the need for Vit E (Combs, 1992).

The retinol content in liver of the Vit E group and the Vit C group was slightly higher than that of the control group ($P=0.052$). This could have been caused by either Vit E or Vit C, but the animals were fed to a weight of about 105 kg and, therefore, were not slaughtered at the same age. Since retinol is stored in the liver, the age of the pigs may affect the retinol content of the liver.

In an *in vitro* study (Cort, 1982), 100 mg of either Vit E or ascorbyl palmitate was added to 5 g crystalline Vit A acetate and heated at 45° C for 2 to 15 days. Both elevated the retinol retention, Vit E having the greatest effect. *In vivo,* the interaction between Vit E and retinol is more complicated. The Vit E protects retinol against oxidative destruction and has a retinol-sparing effect on the retinol store in the liver (Elmadfa and Bosse, 1985; Hanck et al., 1991). However, there are antagonistic interactions during resorption in the gut (Fuhrmann et al., 1995; Hanck et al., 1991; Schelling et al., 1995).

The content of thiamin or riboflavin in liver did not differ between the groups of our study.

The vitamin contents of the different longissimus samples were compared (Fig. 4). The longissimus Vit E content of the Vit E supplemented group was not higher than that of the other groups ($P=0.104$). The average Vit E contents were 4.0 ± 0.6 µg/g, 4.9 ± 0.6 µg/g and 3.7 ± 0.5 µg/g wet weight for the control, the Vit C and the Vit E groups, respectively. In a study by Monahan et al. (1992) pigs received a diet with 21.8 mg

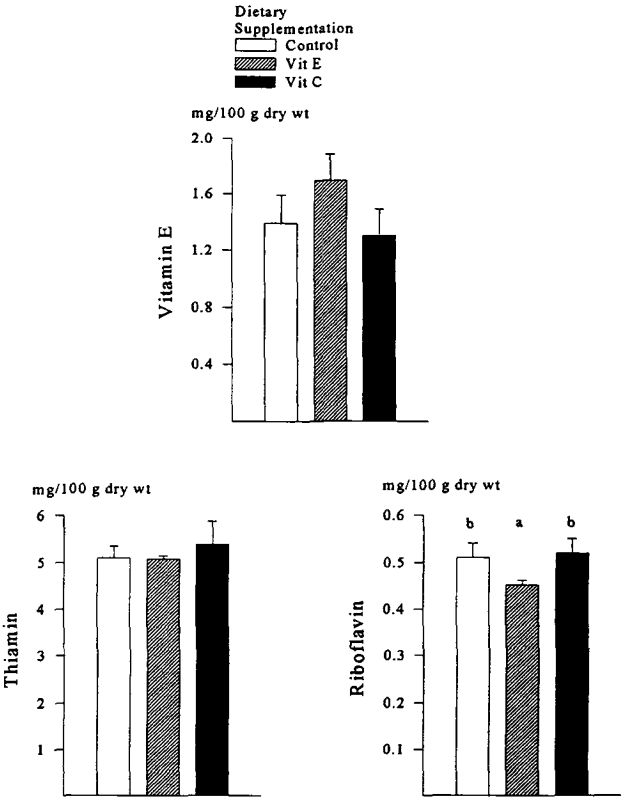

Fig. 4. Influence of α-tocopherol and ascorbate supplementation in pig feed on vitamin concentrations of longissimus dorsi muscle (n=3). Values represent means ± S.D. Means with no common letters differ significantly ($P<0.05$).

Vit E/kg feed for the control group and 204.1 mg Vit E/kg feed for the supplemented group. The resulting longissimus Vit E values were 3.2±0.1 μg/g and 8.0±0.4 μg/g wet weight for the control and the supplemented group, respectively. An explanation for the higher longissimus Vit E content of the supplemented group, in comparison with our study, might be the different content of polyunsaturated fatty acids. Monahan et al. (1992) reported that a substitution of 3% tallow oil with soya oil reduced the Vit E

content of longissimus from 3.2±0.1 μg/g to 2.2±0.2 μg/g and from 8.0±0.4 μg/g to 7.0±0.5 μg/g wet wt for the control and the supplemented group, respectively. The diet we used was high in ingredients like sunflower meal, maize and soybean meal with a high content of polyunsaturated fatty acids. In addition, Schaeffer et al. (1995) reported that tocopherol accumulation was lowest in longissimus, when compared to other muscles like semimembranosus and gluteus medius. This is also in agreement with Flachowsky and Jahreis (1995), who showed that the Vit E content of feed had only a marginal influence on the Vit E content of the longissimus dorsi muscle.

There was no difference of thiamin content in longissimus dorsi muscle between the groups of our study. The riboflavin content of the vitamin E group was lower than that of the other groups ($P<0.05$). The reason for this effect is not known, but the difference (10 %) was marginal.

Vitamin retention after heating

The vitamin contents of the raw liver homogenate and the heated liver samples were compared (Table 9). Retention of Vit E and riboflavin were higher than 100%. An explanation might be that the dry weight was determined by drying at 104°C, whereas during heating of the liver samples, 150°C was reached. At that temperature it is possible that some components (fats and proteins) were disintegrated and volatile products were lost, thus reducing the dry weight. Retention factors for nutrients > 100% have been reported by Ono et al. (1986) and Fox et al. (1994).

The riboflavin content of the heated samples was not different, but the riboflavin retention in the vitamin E and C supplemented groups was higher ($P<0.05$) than that of the control group. Vitamin E and C supplementation of pig diets had a protective effect on riboflavin retention in liver during heating.

The Vit E content of the heated liver samples (Table 9) was different between all groups ($P<0.001$). Also, the retinol content of the heated liver samples of the vitamin E and C groups was higher ($P<0.01$) than that of the control group, but the retinol and Vit E retentions did not differ between groups. The liver samples of all groups showed no difference in thiamin content (absolute and relative).

Vitamin contents of raw muscle homogenates and heated samples were also compared (Table 10). Note that the thiamin and riboflavin losses of the longissimus samples during

Table 9. Vitamin contents of raw homogenate[d] (duplicate analyses) and heated liver samples[d,e]

		Control	Treatment Vitamin E	Vitamin C
α-Tocopherol	Raw	3,88±0,05	8,85±0,07	6,11±0,17
	Heated	4,19±0,12[a]	9,32±0,21[b]	6,53±0,18[c]
	Retention[f]	108±4	105±3	107±3
Retinol	Raw	167,60±0,17	209,75±1,03	201,90±1,09
	Heated	107,33±8,10[a]	134,73±11,97[b]	137,44±7,81[b]
	Retention	64±5	64±6	68±4
Thiamin	Raw	0,98±0,04	1,03±0,02	0,92±0,01
	Heated	0,53±0,08	0,51±0,07	0,52±0,05
	Retention	54±8	50±7	57±5
Riboflavin	Raw	10,15±0,08	10,00±0,20	9,53±0,12
	Heated	11,33±0,32	11,75±0,46	11,45±0,32
	Retention	112±3[a]	118±5[b]	120±3[b]

[a-c]Values in the same row (only heated samples and vitamin retention values) that do not share a common superscript differ significantly ($P<0.05$).
[d]Values represent means ± S.D (mg/100 g dry wt).
[e]Samples from each of three animals of one group were pooled to one sample and distributed onto five dishes.
[f]Values represent %.

preparation were higher than the losses of the liver samples. This could be due to the higher weights of the liver samples, because for preparation the same aluminum dishes were used. Awonorin and Rotimi (1991) reported vitamin retentions in meat samples were enhanced by increased thickness or higher ratio of mass of sample to exposed surface area. Fox et al. (1993a) however, examined the effect of reductant level in skeletal muscle and liver on the rate of loss of thiamin due to γ-radiation. In skeletal muscle the rate of thiamin losses was three times faster than in liver. They explained this effect by the different reducing capacity of liver and skeletal muscle due to higher concentrations of ascorbate, cysteine, reducing sugars and coenzymes in liver.

The riboflavin content of the heated samples as well as the riboflavin retention of the vitamin C supplemented group were higher than those of control group samples ($P<0.05$). Only a few studies examined the effects of radical scavengers on the destruction of thiamin and riboflavin in meat. Fox et al. (1993b) tested free radical scavengers

Table 10. Vitamin contents of raw homogenate[c] (duplicate analyses) and heated longissimus samples[c,d]

		Treatment		
		Control	*Vitamin E*	*Vitamin C*
α-Tocopherol	Raw	1,41±0,28	1,70±0,07	1,48±0,06
	Heated	1,98±0,19	1,72±0,63	1,73±0,38
	Retention	140±13	102±37	117±26
Thiamin	Raw	5,21±0,10	4,74±0,09	4,83±0,27
	Heated	1,48±0,39	1,59±0,35	1,76±0,45
	Retention	28±8	34±7	36±9
Riboflavin	Raw	0,62±0,00	0,56±0,03	0,59±0,00
	Heated	0,45±0,02[a]	0,43±0,01[a]	0,49±0,04[b]
	Retention	73±3[a]	77±2[ab]	83±7[b]

[a,b]Values in the same row (only heated samples and vitamin retention values) that do not share a common superscript differ significantly (P<0.05).
[c]Values represent means ± S.D (mg/100 g dry wt).
[d]Samples from each of three animals of one group were pooled to one sample and distributed onto five dishes.
[e]Values represent %.

and reductants (ascorbate, cysteine, glucose, hydroquinone and isopropanol) for their ability to lessen the loss of thiamin and riboflavin in buffered solutions and in pork during gamma-irradiation. They suggested that the lower losses of B-vitamins in pork, compared to buffered solutions, were related to the presence of sufficient quantities of reductants like ascorbate, cysteine, and hydroquinone. In aqueous solution, the compounds protected riboflavin to a greater extent than thiamin. Our results confirmed this, because only the riboflavin losses during the heating process were reduced. There was no effect on thiamin losses. The reason for this protective effect of vitamin C supplementation on riboflavin retention during heating of pork muscle and liver is not known. No differences were found in the Vit E and the thiamin contents of heated samples, absolute or relative to raw samples.

10. General Discussion

Already our ancestors from the Stone Age consumed meat. They primarily consumed meat from wild animals until the practice of domestication of animals gradually developed (Briggs and Schweigert, 1990; Teuteberg, 1994). On one hand, meat has always been considered a highly valued food, but on the other hand, meat consumption was often combined with some taboos (Briggs and Schweigert, 1990). For example, some religions forbid believers to eat meat of certain species: Jews and Moslems are not allowed to eat meat from pigs and Hindus do not eat beef, because in their religion cows are sacred animals (Kreuzer, 1995).

In Switzerland meat consumption steadily increased after the second world war until the early 1980s. Since that time meat consumption remains stable (Sieber, 1991). Today, there is controversy about the value of meat in human nutrition and mainly three arguments against meat consumption have been raised (Pudel, 1994):

1. Meat consumption and health

Meat contains some undesirable constituents like cholesterol, saturated fatty acids and purines (Wolfram, 1995). A high consumption of saturated fatty acids might increase the biosynthesis of cholesterol and the associated lipoproteins, in particular LDL-cholesterol (Weisburger, 1994). Bodemann et al. (1991) reported that people who ate meat or sausages daily had significantly higher serum cholesterol concentrations than those who ate meat no more than once per week. A high blood cholesterol concentration is one risk factor of coronary heart diseases (Bodemann et al., 1991). Further, Thorogood et al. (1994) reported that non-meat eaters had a reduced mortality rate from cancer, compared to meat eaters. Also, other studies showed that there might be an association between meat consumption and cancer (Vatten et al., 1990, Lee et al., 1991 and Levi et al., 1993).

2. Contamination of meat

Surely, the most important question at present is, if there is an association between the mad cow disease (bovine spongiform encephalopathy) and the new cases of Creutzfeld-

Jacob disease. These new human cases in Great Britain showed a changed aspect of the disease: Usually, affected people are about 60 years, but these people were much younger (Frankhänel, 1996). The likelihood of transmission from cow to people seems to be low (Prusiner, 1995). However, the mad cow disease has afflicted more than 160,000 cattle in Great Britain and many people continue to worry that they will eventually fall ill as a result of having consumed tainted meat (Prusiner, 1995; Frankhänel, 1996).

3. Ethical and ecological consideration

Pictures and articles about cruelty by fattening, transportation and slaughtering animals deeply confused the consumer (Pudel, 1994). In addition, more and more people start to think about the fact that animals are consuming cereals that might also be food for millions of people (Dutra-de-Oliveira and Marchini, 1991). For example, poultry requires approximately 8-10 joules of food energy to produce meat with an energy content of one joule (Chen, 1991). Also, the world livestock population, including cattle, sheep, pigs, goats, and other animals, are presumably the third largest source of methane, which burden our environment (Chen, 1991).

A lactoovovegetarian diet based on plant foods, eggs and dairy products can meet the nutrient requirement of adults, whereas a diet without meat is not recommended for children, adolescents, pregnant women and lactating women (German Nutrition Society, 1996). Infants and children receiving a vegetarian diet are in danger of not meeting their requirement for protein, possibly fat, trace elements and especially vitamin B_{12} (Grüttner, 1989). Different studies provide evidence that exclusively breast-fed babies of mothers with vitamin B_{12} deficiency are at risk of severe developmental and thriving disorders (Stötter and Mayrhofer, 1996; Tönz, 1996). Further, Gibson (1994) reported that children are vulnerable to suboptimal zinc status, because of their high zinc requirement for growth. Possibly, their bodies are not able to adapt sufficiently to vegetarian diets by an increased zinc absorption. Today, it is well accepted that every unbalanced diet diminishes the development in children and their intellectual abilities (Brown and Pollitt, 1996). Also, even for adults it is not recommended to renounce all animal products. Milk is an especially important calcium supplier in human nutrition (German Nutrition Society, 1996). However, milk production is always combined with the production of a small

amount of meat. The logical consequence of a lactoovovegetarian diet would be to burn the meat from animals taken out of production (Tönz, 1996). Therefore, the question at issue is not wether we should eat a substantial amount of meat or if we should eat no meat. The crucial question is how much meat can different population groups consume for profiting from the high content of selected vitamins and trace elements without having any harm to health and well being (Wolfram, 1995).

As shown in the present study, even the relatively small amount of lean meat (105 g/d) consumed in Switzerland was an important source of the examined vitamins and trace elements. Beef and pork shoulder were the best sources of iron and zinc. Pork was rich in thiamin and chicken thigh had a comparatively high α-tocopherol content. All examined meat cuts were relatively good sources of riboflavin. Meat is not an exclusive supplier for one of these nutrients and the requirement for the examined nutrients can also be met by the consumption of other foods. However, the high bioavailability of iron and zinc from meat is important. Meat, fish, poultry and offal are the only foods that contain the better available heme iron besides the inorganic iron (nonheme iron). Furthermore, meat contains no iron and zinc absorption inhibiting factors like phytate, tannins, oxalate and fibers. The recommendations for a daily meat consumption of different nutrition societies range between 40-90 g meat/day. From the view of trace element supply, young children, adolescent girls, menstruating women and pregnant women, who are at risk of iron deficiency anaemia and perhaps also zinc deficiency, should consume more meat, compared to those people with high iron stores.

Since the knowledge about heme iron concentration of meat is important for people at risk of iron deficiency and for people at risk of iron overload, data about the heme iron content should be included in food composition tables. Also, data about the variability of nutrients in meat might be helpful for judging the reliability of nutrient consumption data of different population groups. Generally, it was observed that the contents of nutrients (trace elements and vitamins) in meat, vary to a greater extent, if they are affected by feed composition, compared to those mainly genetically determined.

As shown in a trial with pigs and laying hens, a vitamin E supplementation of the feed significantly increased the α-tocopherol content in all examined products. However, only the increase of the egg yolk α-tocopherol by dietary modification, might be important for human nutrition. The last trial with pigs showed that a vitamin E and also a vitamin C supplementation did not affect the thiamin and riboflavin content of raw liver and longissimus dorsi samples. However, the liver samples of the vitamin C group showed an increased α-tocopherol content compared to the control group. In this context it might be interesting to examine if a vitamin C supplementation also affects the α-tocopherol content of other animal products. In addition, it was shown that dietary vitamin E and C were effective in protecting riboflavin against loss during heating liver samples. Further, a vitamin C supplementation of pig diets had a protective effect on riboflavin retention in longissimus dorsi samples during heating. No positive effect was found on thiamin retention. However, since a vitamin E supplementation might reduce drip losses of the meat, it is possible that also vitamin B losses with the drip are reduced.

In summary vitamin C supplementation of animal feed proved to be an effective way to enhance the liver α-tocopherol content and the riboflavin retention in different animal products.

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12. Appendix

List of appendices

Table 11. Dry weight and contents of selected vitamins and trace elements of pork longissimus dorsi muscle

Samples	Dry weight %	Iron	Heme iron	Zink	α-Tocopherol	Thiamin*	Riboflavin
				mg/100 g wet weight			
1	23.8	0.57	0.36	1.98	0.10	0.63	0.14
2	23.6	0.50	0.29	1.65	0.18	0.85	0.16
3	24.1	0.51	0.27	1.64	0.19	1.02	0.14
4	24.7	0.47	0.17	1.77	0.28	0.76	0.21
5	25.1	0.48	0.30	2.18	0.61	0.64	0.17
6	24.1	0.46	0.32	1.70	0.30	1.02	0.16
7	26.1	0.47	0.22	1.76	0.26	0.81	0.16
8	24.8	0.53	0.26	1.82	0.25	0.90	0.16
9	25.7	0.56	0.29	1.68	0.25	0.38	0.14
10	27.4	0.52	0.27	1.86	0.24	0.82	0.15
11	26.1	0.47	0.26	1.59	0.26	1.15	0.13
12	26.3	0.53	0.31	1.53	0.29	0.89	0.14
13	25.5	0.40	0.20	1.61	0.37	0.48	0.15
14	27.7	0.58	0.21	1.99	0.19	0.84	0.16
15	25.9	0.44	0.24	1.87	0.23	0.59	0.17
16	23.7	0.43	0.27	1.54	0.32	1.09	0.14
17	24.4	0.49	0.28	1.58	0.20	0.61	0.16
18	28.5	0.48	0.39	1.41	0.28	0.98	0.14
19	25.0	0.40	0.23	1.36	0.30	1.19	0.16
20	25.7	0.49	0.36	1.45	0.34	1.16	0.16
21	24.6	0.47	0.31	1.68	0.35	0.66	0.16
22	25.7	0.54	0.30	1.40	0.15	0.65	0.17
23	25.7	0.41	0.30	1.38	0.34	1.23	0.15
24	26.5	0.45	0.34	1.75	0.25	0.72	0.18
25	25.3	0.61	0.36	1.33	0.36	1.04	0.19
Mean	**25.4**	**0.49**	**0.28**	**1.66**	**0.27**	**0.84**	**0.16**
Median	**25.5**	**0.48**	**0.29**	**1.65**	**0.26**	**0.84**	**0.16**
SD	**1.2**	**0.06**	**0.05**	**0.22**	**0.10**	**0.23**	**0.02**
Minimum	**23.6**	**0.40**	**0.17**	**1.33**	**0.10**	**0.38**	**0.13**
Maximum	**28.5**	**0.61**	**0.39**	**2.18**	**0.61**	**1.23**	**0.21**

*** Thiamin chlorid hydrochlorid; SD, standard deviation**

Table 12. Dry weight and contents of selected vitamins and trace elements of pork shoulder muscles

Samples	Dry weight %	Iron	Heme iron	Zink	α-Tocopherol	Thiamin*	Riboflavin
				mg/100 g wet weight			
1	22.9	1.61	1.39	5.14	0.40	0.81	0.31
2	23.2	1.58	0.69	7.00	0.89	0.94	0.28
3	26.2	0.87	0.74	5.01	0.33	0.28	0.4
4	22.6	0.65	0.56	5.62	0.37	0.12	0.3
5	23.2	1.42	0.77	5.60	0.29	1.10	0.3
6	22.5	0.80	0.83	5.40	0.76	1.06	0.32
7	24.5	1.57	1.14	6.78	0.95	0.12	0.42
8	25.1	1.10	0.45	5.39	0.64	0.88	0.38
9	24.8	1.27	0.89	5.96	0.90	0.97	0.35
10	23.1	1.41	0.96	5.70	0.29	1.05	0.27
11	23.5	1.15	0.49	5.98	0.29	1.20	0.29
12	24.6	1.30	1.30	5.91	0.87	0.39	0.41
13	23.9	1.41	1.18	6.20	0.36	0.38	0.23
14	21.4	1.46	0.93	6.09	0.42	1.06	0.27
15	23.4	1.33	0.60	6.14	0.18	0.62	0.21
16	24.1	1.35	0.54	4.19	0.54	0.87	0.26
17	23.6	1.23	0.62	4.15	0.23	0.77	0.25
18	23.6	1.77	0.82	4.62	0.61	0.39	0.29
19	24.3	0.70	0.71	4.17	0.44	0.79	0.25
20	23.3	1.44	1.27	4.84	0.70	0.64	0.47
21	25.6	1.77	0.59	5.05	0.42	0.44	0.32
22	23.4	1.36	0.79	5.43	0.66	0.62	0.33
23	25.2	0.67	0.51	3.10	0.33	0.55	0.34
24	22.9	1.42	0.98	4.86	0.44	0.57	0.31
25	24.1	1.42	0.63	4.70	0.65	0.91	0.28
Mean	**23.8**	**1.28**	**0.82**	**5.32**	**0.52**	**0.70**	**0.31**
Median	**23.6**	**1.36**	**0.77**	**5.40**	**0.44**	**0.77**	**0.30**
SD	**1.1**	**0.32**	**0.27**	**0.89**	**0.23**	**0.31**	**0.06**
Minimum	**21.4**	**0.65**	**0.45**	**3.10**	**0.18**	**0.12**	**0.21**
Maximum	**26.2**	**1.77**	**1.39**	**7.00**	**0.95**	**1.20**	**0.47**

*** Thiamin chlorid hydrochlorid; SD, standard deviation**

Table 13. Dry weight and contents of selected vitamins and trace elements of beef longissimus dorsi muscle

Samples	Dry weight	Iron	Heme iron	Zink	α-Tocopherol	Thiamin*	Riboflavin
	%	mg/100 g wet weight					
1	25.4	1.21	0.99	4.07	0.27	0.039	0.10
2	20.4	1.56	0.78	3.69	0.21	0.056	0.11
3	24.6	2.20	0.99	5.07	0.31	0.034	0.11
4	24.6	2.26	1.03	5.51	0.33	0.038	0.13
5	24.2	2.81	1.50	6.61	0.08	0.058	0.17
6	26.2	2.49	1.16	5.41	0.44	0.039	0.12
7	24.7	2.39	1.09	4.72	0.42	0.039	0.12
8	28.0	3.43	1.72	4.36	0.54	0.045	0.13
9	24.4	2.43	1.10	4.68	0.11	0.051	0.11
10	24.2	1.92	0.92	3.96	0.44	0.050	0.11
11	24.7	1.78	1.05	5.20	0.07	0.056	0.15
12	24.0	1.68	1.14	4.41	0.20	0.050	0.13
13	25.3	1.74	1.26	5.51	0.09	0.032	0.11
14	23.7	1.58	1.08	6.23	0.48	0.028	0.13
15	24.7	1.68	1.24	6.34	0.14	0.040	0.15
16	26.1	1.56	1.30	5.34	0.15	0.046	0.14
17	27.3	2.47	1.67	3.90	0.52	0.039	0.12
18	23.3	1.73	1.35	5.35	0.17	0.055	0.18
19	26.3	1.41	0.88	4.30	0.03	0.055	0.12
20	24.3	2.07	1.47	5.57	0.10	0.034	0.11
21	26.8	1.65	1.19	5.08	0.47	0.037	0.13
22	23.6	1.32	0.96	4.41	0.16	0.035	0.14
23	24.0	1.42	0.99	5.32	0.16	0.039	0.13
24	25.5	1.88	1.34	5.77	0.39	0.043	0.13
25	26.9	1.69	1.06	6.61	0.21	0.046	0.14
Mean	**24.9**	**1.93**	**1.17**	**5.10**	**0.26**	**0.043**	**0.13**
Median	**24.7**	**1.74**	**1.10**	**5.20**	**0.21**	**0.040**	**0.13**
SD	**1.6**	**0.52**	**0.24**	**0.84**	**0.16**	**0.008**	**0.02**
Minimum	**20.4**	**1.21**	**0.78**	**3.69**	**0.03**	**0.028**	**0.10**
Maximum	**28.0**	**3.43**	**1.72**	**6.61**	**0.54**	**0.058**	**0.18**

*** Thiamin chlorid hydrochlorid; SD, standard deviation**

Table 14. Dry weight and contents of selected vitamins and trace elements of beef shoulder muscles

Samples	Dry weight	Iron	Heme iron	Zink	α-Tocopherol
	%		mg/100 g wet weight		
1	22.3	1.83	1.64	6.84	0.18
2	23.8	1.38	1.19	5.70	0.10
3	23.3	1.89	1.12	5.27	0.37
4	22.1	1.55	1.54	5.64	0.16
5	22.0	1.41	1.30	5.16	0.12
6	20.8	1.65	1.56	6.44	0.10
7	22.5	1.35	1.16	5.65	0.11
8	25.0	2.45	2.18	6.72	0.43
9	23.3	1.79	1.32	4.82	0.17
10	21.3	1.89	1.54	7.03	0.26
11	22.1	1.70	1.68	5.71	0.19
12	24.6	1.36	0.99	4.68	0.24
13	23.6	1.77	1.48	4.80	0.15
14	22.3	1.76	1.29	5.98	0.22
15	23.1	2.58	1.88	6.67	0.40
16	24.6	2.06	1.74	7.18	0.69
17	25.7	3.44	2.04	6.93	0.46
18	22.2	1.62	1.75	5.57	0.31
19	25.3	1.37	1.30	4.89	0.10
20	24.5	1.69	1.70	5.39	0.20
21	24.6	1.84	1.89	5.80	0.28
22	25.1	2.03	2.17	5.12	0.18
23	24.7	2.12	1.54	6.88	0.63
24	23.3	1.40	1.16	5.46	0.25
25	23.3	1.82	1.58	4.55	0.24
Mean	**23.4**	**1.83**	**1.55**	**5.79**	**0.26**
Median	**23.3**	**1.77**	**1.54**	**5.65**	**0.22**
SD	**1.3**	**0.46**	**0.33**	**0.82**	**0.16**
Minimum	**20.8**	**1.35**	**0.99**	**4.55**	**0.10**
Maximum	**25.7**	**3.44**	**2.18**	**7.18**	**0.69**

*** Thiamin chlorid hydrochlorid; SD, standard deviation**

Table 15. Dry weight and contents of selected vitamins and trace elements of veal longissimus dorsi muscle

Samples	Dry weight	Iron	Heme iron	Zink	a-Tocopherol	Thiamin*	Riboflavin
	%	mg/100 g wet weight					
1	24.7	0.95	0.78	3.91	0.23	0.09	0.20
2	22.8	0.48	0.59	2.64	0.36	0.14	0.21
3	23.0	0.30	0.35	2.28	0.20	0.11	0.19
4	22.3	0.27	0.21	2.16	0.24	0.05	0.15
5	23.6	0.64	0.51	2.17	0.30	0.07	0.2
6	24.2	0.70	0.67	2.67	0.12	0.05	0.17
7	22.6	0.45	0.42	2.15	0.44	0.06	0.19
8	23.0	0.32	0.36	2.26	0.16	0.07	0.19
9	22.8	0.41	0.68	2.42	0.31	0.08	0.17
10	23.2	0.23	0.21	2.11	0.13	0.04	0.16
11	24.5	0.49		2.53	0.40	0.08	0.21
12	24.0	0.41	0.35	2.66	0.32	0.10	0.19
13	21.9	0.37	0.66	2.54	0.37	0.13	0.17
14	20.4	0.33	0.26	1.96	0.24	0.04	0.19
15	24.2	0.44	0.44	2.52	0.26	0.07	0.21
16	23.8	0.33	0.29	2.33	0.17	0.08	0.18
17	23.0	0.25	0.54	2.14	0.42	0.05	0.17
18	23.9	0.33		2.20	0.54	0.09	0.19
19	23.1	0.32	0.32	2.48	0.47	0.05	0.19
20	24.1	0.41	0.46	3.31	0.31	0.06	0.2
21	23.2	0.28	0.26	1.95	0.32	0.11	0.2
22	24.5	0.39	0.30	2.50	0.23	0.07	0.18
23	24.3	0.49	0.69	3.02	0.21	0.11	0.18
24	24.3	0.27	0.20	2.55	0.12	0.09	0.16
25	23.9	0.31	0.36	2.63	0.34	0.09	0.2
Mean	**23.4**	**0.41**	**0.43**	**2.48**	**0.29**	**0.08**	**0.19**
Median	**23.6**	**0.37**	**0.36**	**2.48**	**0.30**	**0.08**	**0.19**
SD	**1.0**	**0.16**	**0.18**	**0.43**	**0.11**	**0.03**	**0.02**
Minimum	**20.4**	**0.23**	**0.20**	**1.95**	**0.12**	**0.04**	**0.15**
Maximum	**24.7**	**0.95**	**0.78**	**3.91**	**0.54**	**0.14**	**0.21**

*** Thiamin chlorid hydrochlorid; SD, standard deviation**

Table 16. Dry weight and contents of selected vitamins and trace elements of chicken breast

Samples	Dry weight	Iron	Heme iron	Zink	a-Tocopherol	Thiamin*	Riboflavin
	%			mg/100 g wet weight			
1	24.0	0.36	0.17	0.67	0.55	0.06	0.15
2	23.7	0.35	0.17	0.54	0.82	0.20	0.14
3	24.4	0.37	0.20	0.66	0.84	0.15	0.13
4	23.1	0.25	0.20	0.55	0.75	0.10	0.12
5	23.6	0.40	0.14	0.66	0.79	0.13	0.13
6	24.9	0.32	0.11	0.55	0.64	0.06	0.15
7	24.2	0.34	0.13	0.58	0.97	0.12	0.13
8	24.0	0.41	0.18	0.70	0.93	0.17	0.16
9	23.6	0.31	0.16	0.59	0.42	0.10	0.14
10	24.0	0.34	0.15	0.62	0.89	0.14	0.15
11	23.5	0.34	0.16	0.68	0.78	0.13	0.14
12	23.0	0.32	0.14	0.65	0.39	0.23	0.17
13	23.9	0.38	0.16	0.62	0.65	0.12	0.15
14	24.4	0.44	0.15	0.71	0.65	0.14	0.15
15	22.8	0.27	0.12	0.62	0.21	0.09	0.14
16	24.2	0.41	0.15	0.68	0.93	0.12	0.15
17	23.9	0.36	0.16	0.67	0.43	0.08	0.16
18	23.9	0.33	0.11	0.64	0.87	0.12	0.15
19	24.0	0.46	0.15	0.74	0.44	0.09	0.18
20	24.0	0.38	0.15	0.67	0.46	0.03	0.15
21	23.8	0.33	0.15	0.55	0.56	0.10	0.16
22	24.6	0.34	0.16	0.59	0.38	0.06	0.15
23	24.0	0.41	0.17	0.67	0.43	0.11	0.17
24	24.6	0.37	0.18	0.66	0.45	0.15	0.18
25	23.9	0.33	0.14	0.67	0.36	0.15	0.19
Mean	**23.9**	**0.36**	**0.15**	**0.64**	**0.62**	**0.12**	**0.15**
Median	**24.0**	**0.35**	**0.15**	**0.66**	**0.64**	**0.12**	**0.15**
SD	**0.5**	**0.05**	**0.02**	**0.05**	**0.22**	**0.05**	**0.02**
Minimum	**22.8**	**0.25**	**0.11**	**0.54**	**0.21**	**0.03**	**0.12**
Maximum	**24.9**	**0.46**	**0.20**	**0.74**	**0.97**	**0.23**	**0.19**

*** Thiamin chlorid hydrochlorid; SD, standard deviation**

Table 17. Dry weight and contents of selected vitamins and trace elements of chicken thigh

Samples	Dry weight %	Iron	Heme iron	Zink	a-Tocopherol	Thiamin*	Riboflavin
				mg/100 g wet weight			
1	24.1	0.66	0.37	1.78	1.24	0.11	0.25
2	22.7	0.75	0.45	1.72	2.01	0.17	0.24
3	21.5	0.58	0.45	1.70	1.92	0.13	0.25
4	23.7	0.62	0.44	1.54	1.63	0.11	0.24
5	24.4	0.68	0.54	1.76	1.68	0.13	0.23
6	22.0	0.62	0.39	1.79	1.09	0.08	0.23
7	22.6	0.61	0.41	1.74	1.65	0.11	0.2
8	21.4	0.58	0.40	1.52	1.77	0.15	0.22
9	21.9	0.63	0.38	1.86	0.65	0.10	0.26
10	22.5	0.61	0.45	1.78	1.05	0.15	0.25
11	22.3	0.67	0.46	1.52	1.61	0.17	0.24
12	23.4	0.68	0.53	1.54	0.71	0.21	0.25
13	21.5	0.71	0.46	1.61	1.56	0.15	0.25
14	21.2	0.55	0.46	1.35	1.19	0.16	0.33
15	22.3	0.69	0.40	1.62	0.26	0.17	0.2
16	24.1	0.77	0.53	1.61	1.99	0.16	0.28
17	22.4	0.74	0.46	1.68	0.84	0.17	0.26
18	20.9	0.50	0.44	1.52	1.83	0.13	0.25
19	21.5	0.71	0.67	1.44	0.84	0.10	0.27
20	23.0	0.76	0.48	1.45	0.95	0.10	0.29
21	21.8	0.63	0.47	1.37	1.14	0.12	0.33
22	24.7	0.57	0.43	1.48	0.66	0.13	0.22
23	22.3	0.58	0.49	1.49	0.68	0.13	0.28
24	22.6	0.68	0.49	1.74	0.52	0.15	0.32
25	22.3	0.60	0.53	1.65	0.51	0.14	0.33
Mean	**22.5**	**0.65**	**0.46**	**1.61**	**1.20**	**0.14**	**0.26**
Median	**22.3**	**0.63**	**0.46**	**1.61**	**1.14**	**0.13**	**0.25**
SD	**1.0**	**0.07**	**0.06**	**0.14**	**0.53**	**0.03**	**0.04**
Minimum	**20.9**	**0.50**	**0.37**	**1.35**	**0.26**	**0.08**	**0.20**
Maximum	**24.7**	**0.77**	**0.67**	**1.86**	**2.01**	**0.21**	**0.33**

*** Thiamin chlorid hydrochlorid; SD, standard deviation**

CURRICULUM VITAE

Monika Leonhardt

June 20, 1966	born in Erwitte as a citizen of Germany
1972-1976	Primary School in Bad Westernkotten, Germany
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1985-1991	Studies of Home Economics and Nutritional Sciences (Oecotrophologie) at the University of Bonn (Germany)
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