

Arachidonic acid and long-chain n-3 polyunsaturated fatty acids in chicken and turkey meat in relation to dietary fat sources

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Quantitatively and qualitatively most important metabolites of the indispensable polyunsaturated fatty acids (PUFA) of the n-6 (linoleic acid, LA) and the n-3 (α -linolenic acid, LNA) series are arachidonic acid (AA), and eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), respectively. In the present experiment, AA content, long-chain n-3 PUFA equivalent (LCE; calculated as 0.15 LNA + EPA + DHA), and PUFA n-6/PUFA n-3 ratio was determined in breast meat (BM) and thigh meat (TM) within four sets of chickens and five sets of turkeys, respectively, fed either the commercial diet or the diets with manipulated PUFA n-3 and PUFA n-6 content. AA content was within the range of 25 mg/100 g (BM of turkeys fed the diet with fish oil, FO) to 138 mg/100 g (TM of chickens fed restrictively the diet based on maize to the age of 90 days). LCE was in the range 16 mg/100 g (BM of turkeys fed a commercial feed mixture) to 260 mg/100 g (TM of turkeys fed the diet with FO). Both BM and TM of turkeys fed the diet with either linseed oil or FO met the recommended value of the PUFA n-3/PUFA n-3 ratio (lower than 4). AA content in meat increased significantly ($P<0.001$) with increasing dietary LA both in all chicken and turkey tissues, which is contrary to the suggested strong metabolic regulation of the AA formation. When all analysed meat samples were taken as a one set, both AA percentage and EPA+DHA percentage in the tissue (Y, %) decreased ($P<0.001$) with increasing fat content in the tissue (X, %) according to the equation $Y = 5.1 - 0.59X$ ($R^2 = 0.38$) and $Y = 4.7 - 0.70X$ ($R^2 = 0.33$), respectively, and AA content decreased linearly ($P<0.01$) with increasing live weight reached at the slaughter age.

Keywords: chicken; turkey; n-3 PUFA; n-6 PUFA; tissue fat

Introduction

The importance of a relatively high intake of polyunsaturated fatty acids (PUFA) in human nutrition is nowadays generally accepted; PUFA should constitute 7 % of total energy consumed (Ralph, 2000). Within PUFA, fatty acids essential for man are linoleic acid (C18:2n-6; LA) and α -linolenic acid (C18:3n-3; LNA), the precursors of PUFA n-6 and n-3 series, respectively. Quantitatively and qualitatively most important metabolites of LA and LNA are arachidonic acid (C20:4 n-6; AA), and eicosapentaenoic acid (C20:5 n-3; EPA) and docosahexaenoic acid (C22:6 n-3; DHA).

Eicosanoids (prostaglandins, thromboxanes, leucotrienes) derived from AA on the one hand, and EPA and DHA on the other hand, have a different physiological effect on man (vonShacky, 2001). Proinflammatory and proaggregatory AA derived eicosanoids increase the risk of cardiovascular and autoimmune diseases (Adam, 2003). On the other hand, anti-inflammatory, antithrombotic, antiarrhythmic and immunomodulating properties of EPA and DHA can be helpful in the prevention of atherosclerosis, coronary heart diseases, hypertension, inflammatory and autoimmune disorders, cancers and diabetes. From the above-mentioned follows the demand to keep the proper n-6/n-3 PUFA ratio in the diet, preferably 2 or below (Okuyama et al., 1997). Due to the current limited availability

and high cost of fish and low acceptance of fish meat to many consumers, poultry meat and eggs enriched by n-3 PUFA seems to be a feasible alternative to meet this recommendation. Fish oil (Leskanich and Noble, 1997), linseed oil and rapeseed oil (López-Ferrer et al., 1999) are used most commonly in the diets with an aim to manipulate the n-3 PUFA composition of poultry meat.

First objective of the present study was to compare AA content, long chain PUFA content and PUFA n-6/PUFA n-3 ratio in different tissues within two poultry species most commonly consumed in Europe. Secondly, some generalized relationships between AA content, EPA+DHA content and PUFA n-6/PUFA n-3 ratio in the tissue on the one hand, and dietary LA, dietary LNA and LA/LNA ratio in the diet, respectively, fat content in the tissue, and live weight reached at the slaughter age (i.e. growth intensity) on the other hand was assessed.

Materials and methods

Nine sets of experimental animals (including the diets and the methods of fattening) are characterized in *Table 1*. Immediately after slaughter, following tissues were separated: in chickens breast muscles without skin and external visible fat (breast meat, BM), and thigh muscles without skin and external visible fat (thigh meat, TM); in turkeys *musculus pectoralis profundus* (breast meat, BM), and *m. biceps femoris + m. semitendinosus + m. semimembranosus* (thigh meat, TM), both parts rid of skin and visible external fat. The separated tissues were homogenized, total lipids were extracted with hexane/2-propanol (HIP) mixture and fatty acid methyl esters were separated using HP 4890 chromatograph (Hewlett-Packard) and capillary column Omegawax TM250 30 m x 0.25 mm x 0.25 µm. The equivalent of long chain n-3 PUFA (LCE; in mg/100 g of the tissue) was calculated from determined content of LNA, EPA and DHA according to Ollis et al. (1999): LCE = 0.15 LNA + EPA + DHA.

Table 1. Sets of experimental animals, diets characterization and the methods of fattening

Set	Animal species	Number	Age at slaughter (days)	Live weight at slaughter (g)	Diet	Method of fattening
1	chicken ¹⁾	48	43	1100-2500	commercial	<i>ad libitum</i>
2	chicken ¹⁾	12	87	2200	wheat/maize meal 2:1	restrictive
3	chicken ¹⁾	12	90	2200	wheat/maize meal 1:2	restrictive
4	chicken ¹⁾	12	74	2200	wheat/maize meal 1:2	<i>ad semi-libitum</i>
5	turkey ²⁾	53	140	14000-24000	commercial	<i>ad libitum</i>
6	turkey ²⁾	14	56	3370	commercial	<i>ad libitum</i>
7	turkey ²⁾	14	56	3370	commercial + LO ³⁾	<i>ad libitum</i>
8	turkey ²⁾	14	56	3370	commercial + SO ⁴⁾	<i>ad libitum</i>
9	turkey ²⁾	14	56	3370	commercial + FO ⁵⁾	<i>ad libitum</i>

¹⁾Ross 208; ²⁾BUT Big 6; ³⁾linseed oil added to the commercial feed mixture in the amount of 5 % of the fresh matter; ⁴⁾sunflower oil added to the commercial feed mixture in the amount of 5 % of the fresh matter; ⁵⁾FO – fish oil added to the commercial feed mixture in the amount of 5 % of the fresh matter

Results and discussion

Total lipid content (HIP extract) in the evaluated tissues was in the range 0.7 (BM of turkeys fed a commercial diet) to 5.2 g/100 g (TM of chickens fed *ad semi-libitum* to the age of 74 days with a diet based on maize).

Very high AA content (*Figure 1*) was found (as far as breast meat is concerned) in chickens fed intentionally slow to the higher age, especially in chickens fed restrictively the diet based on maize (AA content 91 mg/100 g, set 3a in *Figure 1*). The probable reason was very unfavourable PUFA n-6/PUFA n-3 ratio in the diet within the set 3 (24.6) and the longer duration of feeding. AA content in BM and TM of chickens fed the commercial feed mixture (1a and 1b in *Figure 1*) was substantially

lower in comparison with the corresponding data of Taber et al. (1998): 64 and 106 mg of AA/100 g in the retail BM and TM samples, but was comparable in the case of turkey TM. Li et al. (1998) reported AA content in lean meat of different species to be in the range 30 – 99 mg/100 g, which is similar to our results. Addition of sunflower oil (with high content of linoleic acid and therefore high PUFAn-6/PUFAn-3 ratio) in the diet increased ($P<0.01$) AA content in turkey breast meat (59 mg/100 g; 8a in *Figure 1*) in comparison with turkeys fed the commercial feed mixture (5a and 6a, respectively, *Figure 1*) in the present experiment.

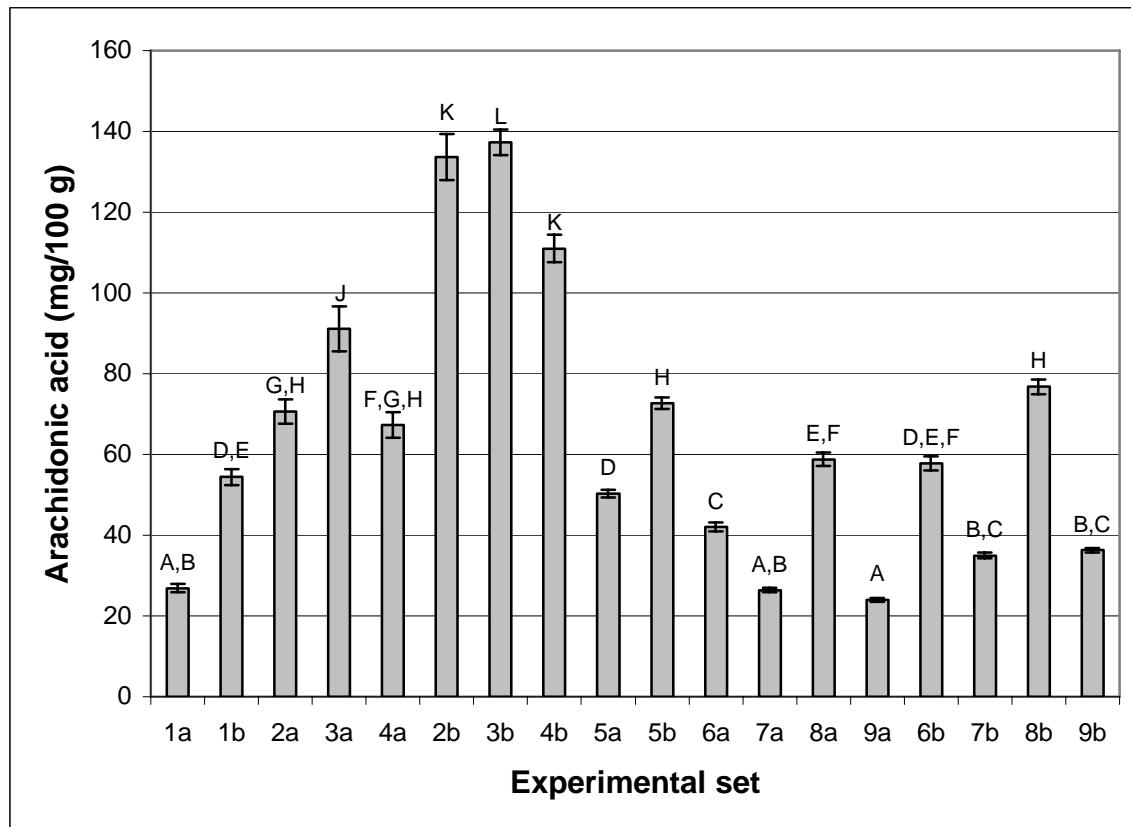


Figure 1. Arachidonic acid content in breast meat (a) and thigh meat (b) of male chickens fed by a commercial feed mixture and slaughtered at the age 43 days ($n = 49$; set 1); female chickens fed restrictively to the age of 87 days with a diet based on wheat ($n = 12$; set 2); female chickens fed restrictively to the age of 90 days with a diet based on maize ($n = 12$; set 3); female chickens fed *ad semi-libitum* to the age of 74 days with a diet based on maize ($n = 12$; set 4); turkey males fed by a commercial feed mixture to the age of 140 days ($n = 53$; set 5); turkeys (the same number of males and females) taken at the age of 56 days fed either a commercial diet ($n = 14$; set 6), or a commercial diet with added linseed oil ($n = 14$; set 7), sunflower oil ($n = 14$; set 8) and fish oil ($n = 14$; set 9), respectively, in the amount of 5 % of the fresh matter; A,B,C,D,E,F,G,H,J,K,L – means with different superscripts differ significantly ($P<0.01$)

When expressed on the relative basis as a percentage of total determined fatty acids, AA (Y, %) decreased significantly ($P<0.001$) with increasing fat content (X, %) in all evaluated tissues. The overall regression (all tissues within both bird species evaluated as a one set, $n = 388$) was $Y = 5.1 - 0.59 X$ ($R^2 = 0.39$). This relationship is possible to explain based on the data of (DeSmet et al., 2004), who reported much higher linoleic acid/α-linolenic acid ratio in the lean meat than in meat with a higher fat level, because LA (a metabolic precursor of arachidonic acid in the animal tissues) is preferably deposited in membrane phospholipids as compared to a storage triacylglycerol fraction.

The dependence of the AA percentage in the tissue (Y, % of total FA) on LA content in the diet (X, % of total FA) was significant ($P<0.0001$) both in the set of all analyzed chicken tissues ($Y = -3.9 + 0.16X$; $R^2 = 0.17$) and all corresponding turkey tissues ($Y = 0.6 + 0.10X$; $R^2 = 0.26$). This finding seems contrary to the data of Baylin and Campos (2004), who, in accordance with the suggested strong metabolic regulation of the AA formation, reported no increase of AA in the human tissues with increasing dietary LA.

In comparison with AA content, the sets of corresponding poultry tissues were more homogenous as far as LCE content in the present experiment is concerned (Figure 2). As regards breast meat, only turkeys fed the diet with linseed oil deposited more ($P<0.01$) LCE (71 mg/100 g; 7a in Figure 2) as compared to the all other poultry sets, except turkeys fed the diet with fish oil, which had still higher ($P<0.01$) content of LCE (123 mg/100 g; 9a in Figure 2). The above-mentioned value regarding linseed oil fed birds correspond with the EPA + DHA percentage 9.0 %, which is much higher figure in comparison with BM of chickens fed the diet enriched by 8.2 % of linseed oil in the experiment of López-Ferrer et al. (1999): 2.1 %. The likely reason is nearly twice as higher EPA + DHA content in the particular diet in the present experiment (1.1).

The deposition of LCE (Y; mg/100 g) in breast meat of poultry differing in live weight at the slaughter age (X) was different between chickens (increase: $Y = 8.3 + 0.008X$, $R^2 = 0.11$, $P = 0.038$; X in g) and turkeys (decrease: $Y = 24.9 - 0.005X$, $R^2 = 0.24$, $P = 0.000$; X in tens of g).

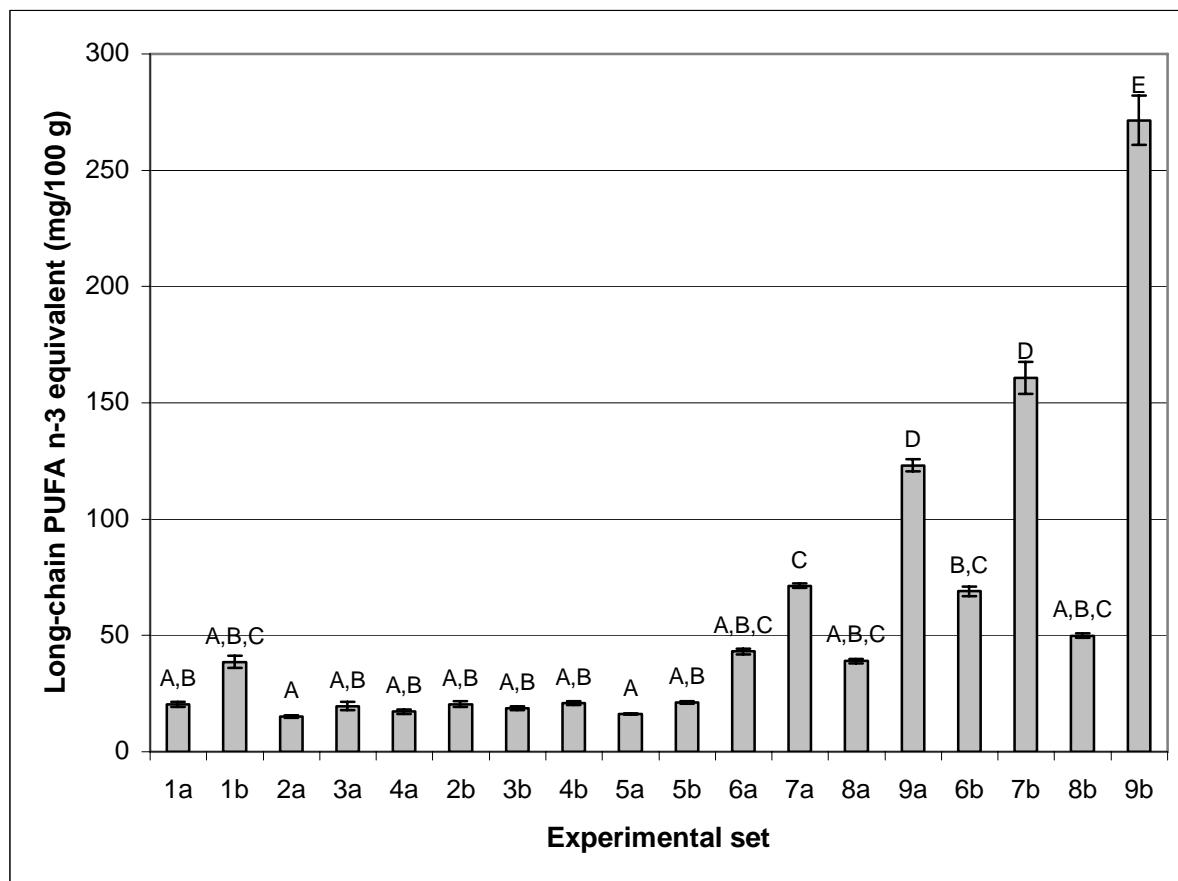


Figure 2. Content of long chain (LC) n-3 polyunsaturated fatty acids (calculated as LC equivalent, LCE = 0.15 α -linolenic acid + eicosapentaenoic acid + docosahexaenoic acid; all components in mg/100 g of meat) in breast meat (a) and thigh meat (b) of chickens and turkeys, respectively; set 1 – 9 see Figure 1; A,B,C,D,E – means with different superscripts differ significantly ($P<0.01$)

EPA+DHA percentage in the tissue (Y, %) decreased significantly ($P<0.001$) in all tissues with increasing fat content in the tissue in the present experiment. The overall regression (when both poultry species and all tissues were taken as a one set) was in the form $Y = 4.7 - 0.70X$ ($R^2 = 0.33$). In this case the finding is contrary to the data of DeSmet et al. (2004), who suggested more equal partitioning of α -linolenic acid (a precursor of long-chain PUFAn-3) between storage triacylglycerols and membrane phospholipids on the one hand and not negligible *de novo* synthesis of longer chain fatty acids of the n-3 series in the membranes on the other hand, with a probable consequence of a weak relationship between fat content and EPA+DHA content in the muscle tissue.

Because nowadays it is unrealistic to achieve the above-mentioned optimal PUFAn-6/PUFAn-3 ratio in human nutrition in the societies with the so-called Western-type of consumption, the

nutritional commissions of particular countries recommend the higher value, most commonly 4 – 5 (e.g. the European population reference intake, Ralph, 2000). Chicken breast meat (1a – 4a, *Figure 3*), and especially BM of turkeys fed the commercial feed mixture within the set 6 (6a in *Figure 3*), was not very different from this value in the present experiment. On the other hand, the PUFA_{n-6}/PUFA_{n-3} ratio in chicken thigh meat, including thigh meat of turkeys within the set 5, was substantially higher ($P<0.01$; 1b – 5b, *Figure 3*). The most unfavourable food ($P<0.01$) from the above viewpoint was TM of turkeys fed the diet with five percent of the lipid fraction in the form of sunflower oil (the ratio 16.5; 8b, *Figure 3*).

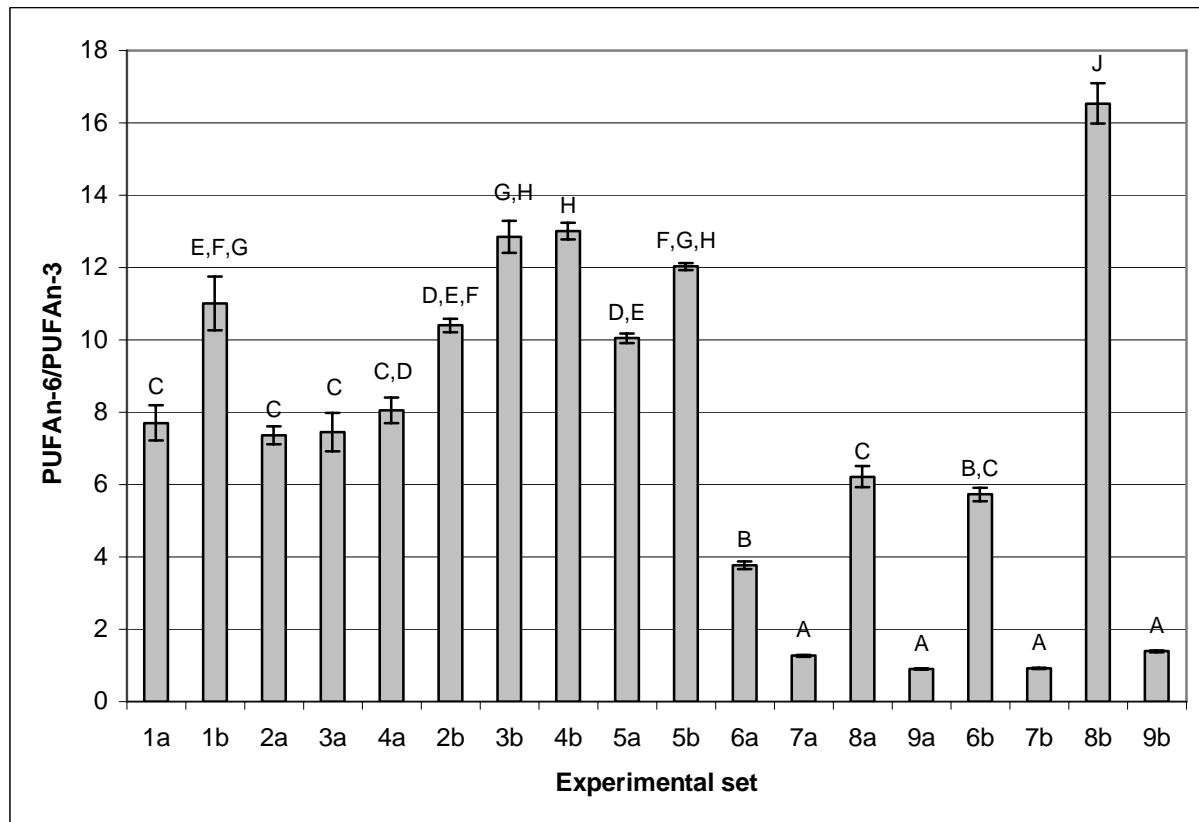


Figure 3. Polyunsaturated fatty acid (PUFA) n-6/n-3 ratio in breast meat (a) and thigh meat (b) of chickens and turkeys, respectively; set 1 – 9 see Figure 1; A,B,C,D,E,F,G,H,J – means with different superscripts differ significantly ($P<0.01$)

Poultry within the experimental sets 1 (chickens) and 5 (turkeys), respectively, were taken within the live weight range as broad as possible in order to be possible to evaluate an effect of the growth intensity (live weight in the fixed, i.e. slaughter age) on fatty acid content. Arachidonic acid content in chicken and turkey BM and in turkey TM decreased linearly with increasing live weight in the slaughter age (43 and 140 days, respectively; *Figure 4*). Inclusion of the quadratic term was not significant in any case. This mechanism could also possibly explain higher ($P<0.01$) AA content in BM and TM of chickens within the set 3 in comparison with the set 4 (*Figure 1*). The diet 3 was fed restrictively and the chickens within the set 3 grew less intensively as compared to the chickens within the set 4, which were offered the diet of an identical composition, but fed *ad semi-libitum*.

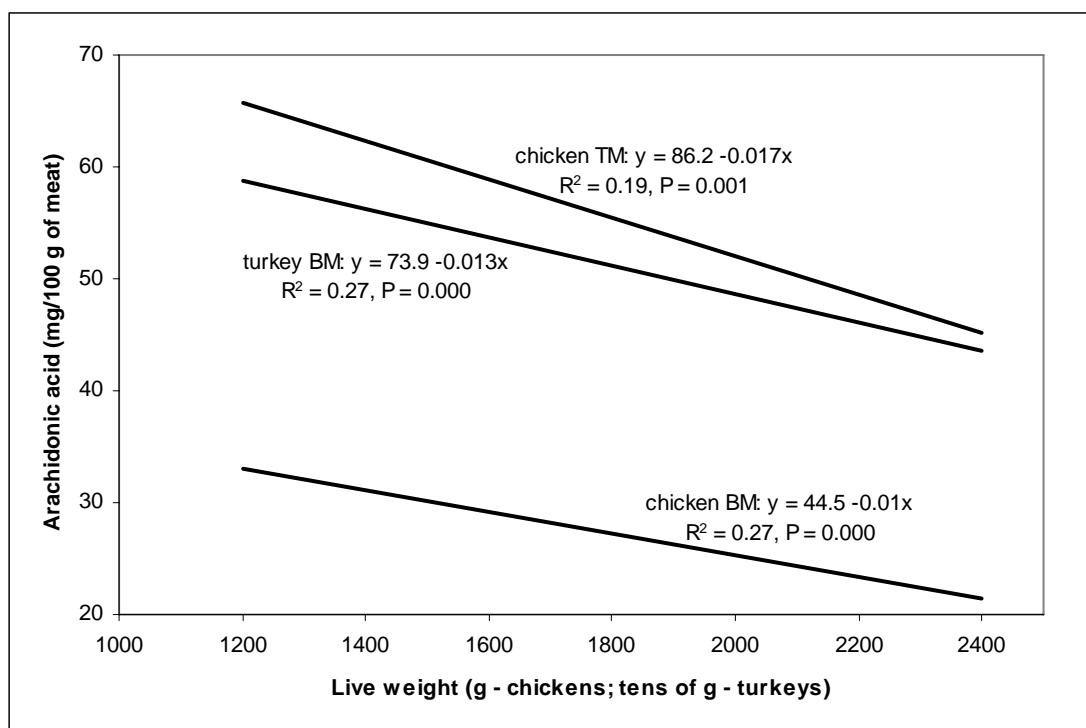


Figure 4. Dependence of arachidonic acid content in breast meat (BM) and thigh meat (TM) of chickens fed by a commercial feed mixture and slaughtered at the age of 43 days (n = 49), and in BM of turkeys fed by a commercial feed mixture and slaughtered at the age of 140 days (n = 53), respectively, on a slaughter live weight

References

RALPH, A. (2000) Appendix: Dietary reference values, in: *Human Nutrition and Dietetics*, 10th edition (J.S. Garrow, W.P.T. James and A. Ralph eds), pp. 849 – 863, Edinburgh: Churchill Livingstone.

DE SMET, S., RAES, K. and DEMEYER, D. (2004) Meat fatty acid composition as affected by fatness and genetic factor: a review. *Animal Research* 53: 81 – 98.

LÓPEZ-FERRER, S., BAUCELLS, M.D., BARROETA, A.C. and GRASHORN, M.A. (1999) N-3 enrichment of chicken meat using fish oil: alternative substitution with rapeseed and linseed oils. *Poultry Science* 78: 356 – 365.

BAYLIN, A. and CAMPOS, H. (2004) Arachidonic acid in adipose tissue is associated with nonfatal acute myocardial infarction in the central valley of Costa Rica. *Journal of Nutrition* 134: 3095 – 3099.

LI, D., NG, A. and SINCLAIR, A.J. (1999) Contribution of meat fat to dietary arachidonic acid. *Lipids* 33: 437 – 440.

TABER, L., CHIU, C.-H. and WHELAN, J. (1998) Assessment of the arachidonic acid content in foods commonly consumed in the American diet. *Lipids* 33: 1151 – 1157.

OLLIS, T.E., MEYER, B.J. and HOWE, P.R.C. (1999) Australian food sources and intakes of omega-6 and omega-3 polyunsaturated fatty acids. *Annals of Nutrition and Metabolism* 43: 346 – 355.

VON SHACKY, C. (2001) Clinical trials, not n-6 to n-3 ratios, will resolve whether fatty acids prevent coronary heart disease. *European Journal of Lipid Science and Technology* 103: 423 – 427.

ADAM, O. (2003) Dietary fatty acids and immune reactions in synovial tissue. *European Journal of Medical Research* 8: 381 – 387.

OKUYAMA, H., KOBAYASHI, T. and WATANABE, S. (1997) Dietary fatty acids – the n-6/n-3 balance and chronic elderly diseases. Excess linoleic acid and relative n-3 deficiency syndrome seen in Japan. *Progress in Lipid Research* 35: 409 – 457.

LESKANICH, C.O. and NOBLE, R.C. (1997) Manipulation of the n-3 polyunsaturated fatty acid composition of avian eggs and meat. *World's Poultry Science Journal* 53: 155 – 183.