Influence of n-3 and n-6 polyunsaturated fatty acids on sensory characteristics of chicken meat

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ABSTRACT: The relationship between different levels of n-6 and n-3 PUFA in chicken breast and thigh meat and sensory characteristics of meat was studied. Chickens were fed diets containing 1, 3, 5 or 7 percent of oil made of seeds either of the linseed cultivar Atalante (A) with a high content of α-linolenic acid or of the cultivar Lola (L) with a predominating content of linoleic acid. The meat of chickens fed L showed better sensory characteristics than the meat of birds fed A. If the tissue contained more than 180 mg/100 g of n-3 PUFA, i.e. the thigh meat when chickens were fed 3% or more A and the breast meat when chickens were fed 7% A, significant fishy odour and taste as well as slight oily aftertaste were recorded. Texture, tenderness and juiciness of breast meat did not differ significantly ($P > 0.05$) in groups fed different diets. Thigh meat in the group with 1% A was significantly ($P < 0.05$) more fibrous than in the group with 7% L; however, there were no differences in texture between the other groups. The thigh meat of chickens fed L was tenderer, juicier and tastier than the meat of those fed A. Tenderness and juiciness were the highest in the group fed 7% of L. There is only a limited possibility to increase the intake of n-3 PUFA without any risk of changes in sensory characteristics of meat. If the levels of α-linolenic acid in the diet were 6.5 and 31 g/kg and the n-6/n-3 PUFA ratios in the meat were 3.3:1 and 0.9:1, respectively, the sensory value of TM and BM was not significantly deteriorated.

Keywords: chicken meat; organoleptic properties; linseed oil; PUFA

The content of polyunsaturated fatty acids (PUFA) in poultry meat depends on their content in the diet to a great extent. Enrichment of poultry products with n-3 PUFA may provide an excellent alternative source of these acids in the human diet. In our experiment with feeding different levels of linseed oil made either of the flax cultivar with a high content of α-linolenic acid (LNA) or of the cultivar with a predominating content of linoleic acid (LA), the content of n-3 PUFA in breast meat (BM) and thigh meat (TM) ranged from 28 to 278 and from 69 to 724 mg/100 g of meat, respectively, while that of n-6 PUFA fluctuated from 141 to 498 and from 584 to 1 586 mg/100 g of BM and TM, respectively (Zelenka et al., 2008). This indicates that by means of an inclusion of linseed oil with a high content of LNA in the diet it could be possible to produce poultry meat as a functional food containing high amounts of n-3 PUFA.

Unsaturated lipids readily undergo oxidation to produce peroxides and aldehydes. The oxidative stability of unsaturated lipids decreases as their degree of unsaturation increases. Poultry meat with an enhanced LNA content is more susceptible to oxidative damage than meat with a similar concentration of LA. The balance of volatile compounds resulting from an oxidative breakdown of n-3 PUFA causes the occurrence of fishy aroma and off-taste characteristic of the meat of poultry fed a higher level of n-3 PUFA (Rymer and Givens, 2005).

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Valavan et al. (2006) studied the effect of 1, 2 and 3 percent of linseed oil in broiler ration from day old chicks to 7 weeks of age. The inclusion of oil had no adverse effect on BM and TM quality in terms of sensory assessment (appearance, juiciness, flavour, tenderness and overall acceptability scores). Gonzales-Esquerra and Leeson (2000) found out that BM and TM aroma, taste, flavour, acceptability, aftertaste and off-flavour were not affected in birds given 100 g flaxseed per kg of the diet for 14 days prior to slaughter. In an experiment performed by Bou et al. (2005), consumer acceptability of cooked TM did not show any significant differences when chickens were fed 1.25% of fish oil, linseed oil or animal fat in the last 5 days of fattening. López-Ferrer et al. (1999a) fed to chickens diets enriched with 8% soybean oil, sunflower oil or linseed oil during the whole growth period. Sensory parameters of BM and TM did not show any significant differences between treatments. In another experiment by López-Ferrer et al. (1999b), the sensory properties of BM and TM of chickens fed 8.2% of fish oil were very poor. When fish oil was replaced by the same level of linseed oil for the last 2 weeks before slaughter, BM was scored by sensory panellists as acceptable and TM had a nearly typical chicken flavour. When López-Ferrer et al. (2001) fed to chickens 1% of fish oil, 3% of linseed oil and 4% of tallow for one or two weeks before slaughter, sensory panellists could not identify their TM as being different from the chickens fed a control diet with 8% of tallow.

When trying to produce meat as a functional food with an increased content of n-3 PUFA it is therefore necessary to find a balance between maximising the n-3 PUFA content in edible tissues and maintaining an acceptable taste of the final product.

MATERIAL AND METHODS

Materials and samples preparation

Details about chickens, experimental design, composition of diets, contents of fatty acids in meat, and dependence of fatty acid contents in meat on the level of LA and LNA in the diet were described by Zelenka et al. (2006, 2008) and are briefly summarized below.

The experiment was performed with cockerels of Ross 308 hybrid combination. Birds were fattened from Day 25 of age to Day 40 on feed mixtures containing 1; 3; 5 or 7% of linseed oil made either of seeds of the cultivar Atalante (A) with a predominating content (612 g/kg) of LNA (A1; A3; A5; A7) or seeds of the cultivar Lola (L) with a predominating content (708 g/kg) of LA (L1; L3; L5; L7). Different oil supplements changed the contents of essential fatty acids in individual diets as well as PUFA contents and n-6/n-3 PUFA ratios in BM and TM (Table 1).

For sensory analyses four chickens from each group were used. BM and TM without skin were separated from carcasses after cooling, put into freeze bags, chilled on ice until rigor shortening has passed (24 h) and frozen until the sensory analyses were carried out.

The frozen meat was allowed to thaw to an internal core temperature of 1°C. The BM and TM were individually wrapped in a double aluminium foil, placed on an oven-plate and roasted in an electric household oven at 200°C to the final core temperature of 85°C. The temperature was measured by inserting a digital thermometer into meat.

Sensory analysis

Sensory evaluation was performed by a trained internal sensory panel (Mendel University Brno, Czech Republic) consisting of ten persons. Sensory sessions were conducted in a test room (ISO 8589, 1988) with individual booths. Adapted flavour profile method and texture profile method (Meilgaard et al., 1991; Majou et al., 2001) were used to evaluate the sensory characteristics of samples. Panellists were familiarized with the sensory methodology and sensory attributes during the training sessions. Sensory attributes were selected from those previously reported in the literature (e.g. Poste et al., 1996; Nute, 1999; Gonzales-Esquerra and Leeson, 2000; Valavan et al., 2006) and confirmed during the initial training session.

The 100 mm unstructured line scales with two anchor points were used. The anchor points were placed 15 mm from each end on the scale and were labelled as follows: Odour: unpleasant – very pleasant; texture: finely fibrous – extremely fibrous; tenderness: very tough – very tender; juiciness: very dry – very juicy; total taste: unpleasant – typical chicken flavour; oily aftertaste: without oily aftertaste – very intensive oily aftertaste. In the case of any off-odour and/or off-flavour presence, panellists had to specify it.

Table 1. Fatty acid contents

Tissue	Oil	Level of oil in feed (g/kg)	Content in g/kg of diet		Content in mg/100 g of meat											
			18:2n-6	18:3n-3	18:2n-6	18:3n-6	20:4n-6	22:4n-6	18:3n-3	20:3n-3	20:5n-3	22:5n-3	22:6n-3	n-6	n-3	n-6/n-3
Breast meat	Atalante	10	7.57	6.48	111.1	1.1	23.9	4.8	28.2	1.0	5.7	11.2	8.6	140.9	54.7	2.7
		30	9.89	18.72	165.0	1.3	21.8	4.0	104.9	3.0	10.7	18.9	16.9	192.1	154.3	1.3
		50	12.01	30.97	142.6	1.0	22.9	3.2	129.3	4.2	14.4	25.3	16.1	169.7	189.4	0.9
		70	14.53	43.21	200.9	1.2	23.4	3.0	215.3	5.5	17.0	25.5	15.0	228.5	278.2	0.9
	Lola	10	14.22	0.44	147.5	1.5	37.1	8.9	8.3	0.3	2.6	7.4	9.0	194.9	27.5	7.3
		30	28.78	0.83	222.8	2.2	42.2	11.3	11.4	0.4	2.0	7.3	10.8	278.4	31.9	9.0
		50	43.61	1.23	308.4	2.3	47.5	16.1	17.9	0.5	2.7	7.4	10.5	374.4	39.0	9.9
		70	58.44	1.65	434.6	3.2	45.6	14.5	21.6	0.4	1.8	7.2	7.4	497.9	38.4	13.6
Thigh meat	Atalante	10	7.57	6.48	513.1	5.2	55.7	9.8	130.1	2.1	15.1	21.3	10.9	583.9	179.4	3.3
		30	9.89	18.72	667.3	5.4	49.6	7.0	380.0	5.0	27.5	32.5	13.1	729.1	458.0	1.6
		50	12.01	30.97	601.5	4.4	41.0	5.1	496.4	6.4	29.1	36.6	15.3	652.0	583.8	1.1
		70	14.53	43.21	661.8	4.3	41.8	4.6	635.9	8.7	31.4	36.0	11.8	712.6	723.8	1.0
	Lola	10	14.22	0.44	607.0	6.2	69.1	15.9	43.1	0.1	5.2	10.2	10.7	698.2	69.3	10.1
		30	28.78	0.83	962.2	8.4	76.4	18.4	58.7	0.1	7.0	10.5	11.0	1 065.4	87.3	11.7
		50	43.61	1.23	1 194.2	8.9	95.4	27.4	64.8	0.5	4.3	11.7	13.7	1 325.9	94.9	14.1
		70	58.44	1.65	1 465.1	11.0	85.8	23.7	72.9	0.2	5.0	10.5	8.9	1 585.7	97.5	17.2

After heat treatment, each specimen was cut into ten pieces. This "sub-samples" were presented to the panel in a sequence ensuring that each panellist received the same part of the meat every time. All samples were labelled, randomised and served warm (40–50°C). The odour was evaluated immediately while flavour and texture attributes were evaluated after cutting the sample.

Between samples panellists were required to eat unflavoured bread and rinse their mouth thoroughly with drinking water to minimize the carry-over effect. Eight poultry samples, one chicken from each diet group, were assessed in one session. The sensory evaluation was carried out in four sessions.

Statistical analysis

The data from all the determinations were subjected to analysis of variance by means of the Statistical package STATISTICA, version 6.1 (StatSoft, Inc.) applicable for multifactorial experiments, and the comparison of means was performed by Tukey's test.

RESULTS AND DISCUSSION

Differences in basic production parameters, BM and TM percentages in live weight, and dry matter, ether extract and crude protein contents in meat between the groups receiving oil supplements with different levels of LA and LNA were insignificant ($P > 0.05$) (Zelenka et al., 2006). The fatty acid pattern in the diet substantially influenced the n-6/n-3 PUFA ratio in meat (Zelenka et al., 2008).

The panel mean scores for each attribute of sensory characteristics evaluated on a hundred point scale are listed in Table 2.

The sensory evaluation of BM demonstrated that feeding 1–7% of oil prepared from both flax cultivars did not result in any significant differences in texture, tenderness and juiciness. In odour, there were no significant differences ($P > 0.05$) up to the content of n-3 PUFA 189 mg/100 g of meat. Only in the experimental variant with 7% of oil with a high content of LNA four panellists noticed a slight fishy odour in some specimens. The odour of breast fillet was highly significantly ($P < 0.01$) less agreeable and showed a slight oily aftertaste. However, the intensity of this oily aftertaste did not significantly ($P > 0.05$) differ from that of group L7. The typical flavour of chicken BM was noticed in L1 and L5, and a significantly worse ($P < 0.05$) taste was observed only in the meat of group A7, which contained 278 mg of n-3 PUFA per 100 g. Four panellists noticed a fishy flavour in a half of the tested chickens. Neither did Valavan et al. (2006) notice deteriorated sensory quality even when feeding 3% of linseed oil in broiler mixture. López-Ferrer et al. (1999b) considered BM of chickens fed 8.2% of linseed oil as acceptable.

Substantially greater differences were recorded when evaluating TM, which contained a much higher amount of n-3 PUFA. In accordance with Rymer and Givens (2005) with an increasing degree of unsaturation of dietary fatty acids there was a decrease in meat sensory properties and fishy aroma and oily aftertaste occurred. With the exception of group A1, in which 100 g TM contained 179 mg of n-3 PUFA, the meat of chickens fed A showed a less pleasant odour than the meat of those fed L. The panellists did not detect a fishy flavour even in the meat of chickens with a high level of L in the diet. The most unpleasant odour of meat was recorded in chickens of group A7 again. Three panellists noticed a mild but acceptable fishy odour in some specimens from group A3. In the meat of chickens fed 5 and 7% A this unpleasant odour was detected to be more distinct in 24 and 19 cases out of 40, respectively. No fishy taste was noticed only in chickens fed the lowest level of A. In chickens with 3, 5 and 7% of oil in the diet this fishy taste was noticed in 15, 19 and 22 out of 40 cases in total, respectively. In group A1, the meat texture was significantly ($P < 0.05$) more fibrous than in group L7, and there were no differences between the other groups. Feeding L reduced the toughness of meat and increased its juiciness. In all groups fed L, TM was tenderer, juicier and tastier than in those receiving A. The highest tenderness and juiciness were recorded in the group fed 7% of L. In comparison with the other groups, a significant oily aftertaste ($P < 0.05$) was noticed only in groups with 3, 5 and 7% of A.

Similarly to our results, Bou et al. (2005) did not detect the lower consumer acceptability of TM when feeding 1.25% of linseed oil. Neither did Gonzales-Esquerra and Leeson (2000) with the content of 14.5 g LNA in 1 kg of diet nor Valavan et al. (2006) with 3% of linseed oil in the diet mention reduced sensory quality of TM. We did not

Table 2. Sensory analysis – Tukey's test

Tissue	Oil	Level of oil in feed (g/kg)	*n*	Mean values of sensory characteristics – mm of unstructured line scales					
				odour	texture	tenderness	juiciness	total taste	oily after taste
Breast meat	Atalante	10	40	53.05^{a}	50.53^{a}	50.52^{a}	46.83^{a}	52.50^{ab}	0.08^{b}
		30	40	53.10^{a}	51.55^{a}	49.02^{a}	46.30^{a}	51.58^{ab}	0.63^{b}
		50	40	49.98^{ab}	51.05^{a}	50.00^{a}	49.85^{a}	49.93^{ab}	0.00^{b}
		70	40	44.48^{b}	49.78^{a}	48.70^{a}	48.23^{a}	45.60^{b}	3.43^{a}
	Lola	10	40	54.98^{a}	50.75^{a}	45.50^{a}	48.73^{a}	54.90^{a}	0.15^{b}
		30	40	54.65^{a}	48.73^{a}	48.00^{a}	48.33^{a}	51.40^{ab}	0.48^{b}
		50	40	53.18^{a}	49.93^{a}	43.80^{a}	52.08^{a}	55.45^{a}	0.05^{b}
		70	40	53.85^{a}	51.48^{a}	44.15^{a}	49.05^{a}	52.48^{ab}	1.03^{ab}
Thigh meat	Atalante	10	40	55.40^{bcd}	52.08^{a}	50.55^{a}	51.70^{b}	54.65^{bc}	3.98^{bc}
		30	40	51.50^{cde}	48.93^{ab}	50.37^{a}	50.30^{b}	48.73^{cd}	11.18^{ac}
		50	40	50.03^{de}	50.05^{ab}	50.37^{a}	50.40^{b}	48.38^{cd}	18.38^{a}
		70	40	48.30^{e}	49.13^{ab}	53.37^{ab}	53.58^{b}	42.38^{d}	14.80^{a}
	Lola	10	40	57.38^{abc}	50.23^{ab}	56.22^{ac}	55.65^{ab}	60.30^{ab}	2.78^{bc}
		30	40	58.53^{ab}	48.05^{ab}	56.10^{ac}	54.88^{ab}	60.53^{ab}	1.08^{b}
		50	40	58.75^{ab}	46.78^{ab}	60.30^{bc}	60.28^{a}	63.18^{a}	2.75^{bc}
		70	40	61.68^{a}	46.00^{b}	61.82^{c}	61.00^{a}	61.58^{ab}	1.70^{b}

^{a,b,c,d}means with different superscripts in the same tissue differ significantly $P < 0.05$

confirm the insignificant differences in sensory assessment of BM and TM reported by López-Ferrer et al. (1999a), who fed 8% of linseed oil reach in LNA and the same level of soybean oil or sunflower oil with low levels of LNA. Also in another experiment by López-Ferrer et al. (1999b), TM of chickens fed 8.2% linseed oil for the last 2 weeks before slaughter showed a nearly typical chicken flavour. Sensory panellists in an experiment performed by López-Ferrer et al. (2001) could not identify TM of chickens fed 1% of fish oil, 3% of linseed oil and 4% of tallow and of those fed the control diet with 8% of tallow.

If we want to increase the content of n-3 PUFA and to narrow the n-6/n-3 PUFA ratio by feeding linseed oil with a high level of LNA, from the aspect of taste and oily aftertaste only 1% of such oil should be used in the chicken diet, when TM contains n-3 PUFA 179 mg/100 g, a comparable amount with BM with the 5% level of dietary oil A. At these levels the n-6/n-3 PUFA ratios in BM and TM are equal to 0.9:1 and 3.3:1, so that such meat can be considered as functional food.

The exact requirement of LNA has not been determined reliably yet; only the requirement of LA is defined for the time being. The Committee on Animal Nutrition of the Czech Academy of Agricultural Sciences (Zelenka et al., 2007) recommended that feed mixtures for chickens from Day 25–29 of age till the end of fattening should contain 10 g of LA in 1 kg of feed. When maximising the content of LNA in meat, it is possible to use 6.5 g LNA per 1 kg of feed mixture and this can be reached by the inclusion of 1% of linseed oil reach in LNA. In such a case the n-6/n-3 PUFA ratio in the diet would be 1.5:1.

It can be concluded that it is suitable to use feeding oils with a high level of LNA if we prefer meat with favourable n-6/n-3 PUFA ratio. If we want to produce finely fibrous, juicy and tastier meat, it would be advantageous to include feeding fat with a high level of LA in the diet. For a favourable combination of desirable sensory characteristics with an advantageous level of n-3 PUFA it is advisable to combine both types of oil. In sensory assessment BM, which is preferred by the majority of the consumers, showed a significantly worse odour and overall taste, as well as a slight oily aftertaste only at levels of 278 mg of n-3 PUFA in 100 g of tissue.

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