Effect of dietary lipid source on fatty acid profile, lipid oxidation and sensory acceptability of broiler breast meat

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***Abstract*– Dietary fatty acids are absorbed and deposited in the tissue of monogastric animals without significant modification. The aims of this study were to investigate the effects of different dietary lipid sources and inclusion levels on fatty acid profile, lipid oxidation and sensory acceptability of broiler breast meat. Eight isocaloric and isonitrogenous diets were formulated, using sunflower oil, high oleic sunflower oil, fish oil and tallow at a 30 g/kg and 60 g/kg inclusion level. Eight hundred, day-old Ross 788 broiler males were randomly allocated to the 8 treatments (n=100). Birds were slaughtered at a commercial abattoir at 42 days of age. Chicken breast (n=12/treatment) were used for fatty acid analysis, assessment of lipid oxidation during storage and sensory analysis. Fatty acid composition of dietary lipid sources were reflected in fatty acid profiles of breast meat. Birds fed fish oil showed more ($p < 0.0001$) oxidation in breast meat than birds from any of the other treatments during storage. Meat samples of the high oleic sunflower oil treatment were preferred ($p < 0.0001$), while fish oil samples were the least acceptable ($p < 0.0001$) to the sensory panel. It was demonstrated that it is possible to improve the health properties of chicken by the inclusion of omega-9 (high oleic sunflower oil) or omega-3 (fish oil) in broiler diets. Dietary lipid sources could be used to manipulate sensory characteristics of broiler breast meat but care must be exercised since dietary lipid sources influence the lipid oxidation processes of broiler meat.**

***Keywords*– dietary lipid source, fatty acid profile, lipid oxidation, sensory acceptability, broiler**

I. INTRODUCTION

Dietary fatty acids are absorbed by monogastric animals and deposited in their tissues without significant modification [1]. There is, therefore, potential for the manipulation of the fatty acid profiles of poultry tissue by dietary means to increase the supply of omega-3 (n-3) polyunsaturated fatty acids (PUFA) suitable for human consumption [2].

Eating quality traits (tenderness, juiciness, flavour and overall acceptability) of pork were generally improved as the concentration of MUFA (oleic acid) increased and PUFA (linoleic acid) decreased [3]. It was also demonstrated that sensory quality may be adversely influenced by supplementation with fish oil or other omega-3 PUFA sources eg. linseed [4,5,6].

Increasing the unsaturation degree of muscle membranes reduces the oxidative stability of the muscle. The level of PUFA in n-3 enriched poultry meat can, therefore, play an important role in the susceptibility of poultry meat to lipid oxidation. Lipid oxidation can lead to discolouration, drip-loss during storage, off-odour, off-flavour development and the production of potentially toxic compounds during meat processing [7].

The aims of this study were to determine the effect of different dietary lipid sources (tallow, sunflower oil, high oleic sunflower oil and fish oil) and inclusion levels on the fatty acid profile, sensory acceptability and oxidative stability of broiler breast meat.

II. MATERIALS AND METHODS

A. Broiler experiment

The experimental layout consisted of 4 dietary lipid sources and 2 inclusion levels. 800 x day-old Ross 788 broiler males were randomly allocated to 8 dietary

treatments (n=100/treatment). Each treatment was further subdivided into 4 replicates. Birds received a commercial starter diet for the first 14 days, where-after the experimental diets were fed for 28 days. Eight isocaloric and isonitrogenous diets were formulated, using sunflower oil (SO), high oleic sunflower oil (HOSO), fish oil (FO) and tallow (T) at a 30.0 g/kg and 60.0 g/kg dietary inclusion level. At 42 days of age, 3 birds/replicate (n=12/treatment) were randomly selected, weighed, marked and slaughtered at a commercial abattoir.

B. Fatty acid profile of breast meat

Total lipid was extracted from the breast meat [8]. Fatty acid methyl esters (FAME) were prepared using methanol-BF3 [9]. FAME were quantified using a Varian GX 3400 flame ionization gas chromatograph, with a capillary column (Chrompack CPSIL 88, 100 m length, 0.25 mm ID, 0.2 μm film thickness). Identification of FAME was made by comparing retention times with standards (SIGMA 189-19).

C. Sensory Profile of Breast Meat

Breast muscle samples were lightly-salted and steamed (200ºC) in an oven, until a constant internal temperature of 70ºC was reached. 75 x untrained respondents participated in the consumer acceptance evaluation. The questionnaire consisted of a nine-point hedonic scale [10,11].

D. Oxidative stability of breast meat

Carcasses were cut into portions and left breasts (n=12) were over-wrapped and stored at 4^{o}C for 7 days while right breasts (n=12) were vacuum packed and stored at -18^{o}C for 100 days. Meat samples from each breast and thigh were used for the analysis of the TBARS to determine lipid oxidation [12].

E. Statistical analysis

All data were subjected to analysis of variance (ANOVA). The Tukey-Kramer multiple comparison test (α=0.05) was used to identify differences between treatment means [13].

III. RESULTS AND DISCUSSION

A. Fatty acid profile of breast meat

The fatty acid profiles of the 8 experimental diets were well reflected in the fatty acid profiles of the breast meat (Table 1). This was best illustrated by elevated C18:1 content in meat from the HOSO treatments, elevated C18:2 content in meat from the SO treatments and elevated C20:5, C22:5 and C22:6 content in meat from the FO treatments.

It was possible to bring the n-6/n-3 ratio of lipids in breast meat within the ratio of 2:1 proposed [14] as the ideal ratio to prevent Diseases of Western Civilization.

B. Sensory profile of breast meat

The most preferred meat sample was from birds receiving the diet containing 60 g/kg HOSO (Fig. 1) which was in accordance with another study [3].

Meat samples of the FO treatments were the least acceptable to the consumer panel which confirms other findings [4,5,6]. It also demonstrated that the South African consumer is sensitive to a fishy off-odour because the consumer panel could pick it up in the meat at dietary inclusion levels of 30 g/kg.

The sensory panel could not differentiate between breast meat from birds receiving T and SO diets.

C. Oxidative stability of breast meat

Results in Figures 2 and 3 indicate that lipid source, at especially a high inclusion level (60 g/kg), had an effect ($p < 0.0001$) on fat oxidation during refrigerated storage for 7 days and frozen storage of 100 days for breast meat.

Breasts from birds receiving FO had higher TBARS values compared to breasts from birds receiving T, HOSO or SO. This confirms the findings that more unsaturated fatty acids have a faster rate of oxidation [15].

Breasts from poultry receiving the FO-60 diet had TBARS values exceeding the value of 1 proposed [16] as the cut-off point in terms of rancid tastes.

TBARS values of breasts that were vacuum sealed and stored at -18^{o}C for 100 days seems to be lower

Table 1 Intramuscular fat content (IMFC) and fatty acid (FA) profiles of breast meat from different dietary treatments. Means with different superscripts differ significantly. * = p < 0.05, ** = p < 0.01, *** = p < 0.001

Dietary Treatment:	T-30	T-60	HOSO-30	HOSO-60	SO-30	SO-60	FO-30	FO-60	Sign. level
IMFC	1.6 ± 0.4^{c}	1.4 ± 0.27^{ac}	1.5 ± 0.3^{bc}	1.4 ± 0.3^{ac}	1.5 ± 0.3^{bc}	1.4 ± 0.2^{ac}	1.2 ± 0.2^{ab}	1.1 ± 0.2^{a}	**
C14:0	1.0 ± 0.1^{c}	1.2 ± 0.1^{c}	0.6 ± 0.0^{b}	0.3 ± 0.1^{a}	0.5 ± 0.1^{b}	0.3 ± 0.0^{a}	1.6 ± 0.2^{d}	2.3 ± 0.3^{e}	***
C16:0	24.2 ± 1.1^{e}	22.8 ± 0.9^{cd}	21.2 ± 1.1^{b}	17.2 ± 1.1^{a}	21.6 ± 1.0^{bc}	18.5 ± 1.1^{a}	24.3 ± 1.0^{e}	23.9 ± 1.2^{de}	***
C16:1c9	3.5 ± 0.48^{bc}	3.3 ± 0.58^{bc}	3.1 ± 0.5^{b}	1.9 ± 0.4^{a}	3.1 ± 1.0^{b}	1.4 ± 0.3^{a}	3.9 ± 0.6^{c}	4.0 ± 0.8^{c}	***
C18:0	11.1 ± 1.0^{d}	11.2 ± 0.6^{d}	8.8 ± 0.9^{ab}	8.5 ± 0.6^{ab}	9.3 ± 1.0^{ab}	9.8 ± 0.8^{bc}	10.7 ± 0.9^{cd}	11.3 ± 0.9^{d}	***
C18:1	32.7 ± 1.6^{cd}	34.2 ± 2.2^{d}	40.1 ± 2.9^{e}	45.7 ± 2.1^{f}	30.3 ± 2.3^{c}	27.1 ± 1.5^{b}	26.5 ± 1.7^{b}	22.6 ± 2.4^{a}	***
C18:2 (n-6)	15.8 ± 1.0^{c}	15.3 ± 1.0^{bc}	15.9 ± 0.8^{c}	17.8 ± 0.6^{d}	24.5 ± 1.3^{e}	33.0 ± 2.3^{f}	14.1 ± 1.1^{ab}	12.6 ± 1.2^{a}	***
C18:3 (n-3)	0.9 ± 0.2^{b}	0.8 ± 0.1^{ab}	0.7 ± 0.1^{ab}	0.7 ± 0.1^{ab}	0.7 ± 0.1^{ab}	0.8 ± 0.1^{ab}	0.7 ± 0.3^{ab}	0.7 ± 0.1^{a}	*
C20:1	0.3 ± 0.0^{ac}	0.3 ± 0.0^{bc}	0.3 ± 0.0^{cd}	0.4 ± 0.0^{d}	0.2 ± 0.0^{ab}	0.2 ± 0.0^{a}	0.3 ± 0.1^{bc}	0.4 ± 0.1^{d}	***
C20:2 (n-6)	0.4 ± 0.1^{ab}	0.4 ± 0.1^{ab}	0.4 ± 0.1^{ab}	0.5 ± 0.1^{bc}	0.6 ± 0.2^{c}	0.9 ± 0.2^{d}	0.3 ± 0.0^{a}	0.3 ± 0.1^{a}	***
C20:3 (n-3)	0.6 ± 0.2^{ac}	0.8 ± 0.1^{c}	0.6 ± 0.2^{bc}	0.6 ± 0.2^{ab}	0.7 ± 0.2^{bc}	0.6 ± 0.1^{ab}	0.5 ± 0.1^{ab}	0.5 ± 0.1^{a}	***
C20:49 (n-6)	2.9 ± 0.8^{ab}	3.8 ± 0.8^{bc}	3.0 ± 0.8^{ab}	4.8 ± 0.8^{c}	3.7 ± 1.0^{bc}	6.1 ± 1.4^{d}	2.1 ± 0.3^{a}	2.2 ± 0.4^{a}	***
C20:5 (n-3) (EPA)	1.2 ± 0.6^{c}	1.0 ± 0.2^{bc}	0.9 ± 0.3^{bc}	0.2 ± 0.1^{a}	0.7 ± 0.1^{b}	0.0 ± 0.1^{a}	3.6 ± 0.5^{d}	4.9 ± 0.8^{e}	***
C22:5 (n-3) (DPA)	1.7 ± 0.5^{b}	1.4 ± 0.4^{b}	1.5 ± 0.4^{b}	0.6 ± 0.2^{a}	1.4 ± 0.4^{b}	0.5 ± 0.2^{a}	3.8 ± 0.7^{c}	4.3 ± 1.0^{c}	***
C22:6 (n-3) (DHA)	3.0 ± 1.3^{b}	2.2 ± 0.6^{b}	2.5 ± 0.6^{b}	0.5 ± 0.2^{a}	2.4 ± 0.6^{b}	0.4 ± 0.1^{a}	7.2 ± 1.7^{c}	9.6 ± 2.3^{d}	***
SFA	36.9 ± 1.8^{d}	36.0 ± 1.2^{d}	30.8 ± 1.8^{c}	26.3 ± 1.5^{a}	31.6 ± 1.0^{c}	28.8 ± 1.7^{b}	36.9 ± 1.5^{d}	37.9 ± 1.9^{d}	***
MUFA	36.7 ± 1.9^{de}	38.3 ± 2.8^{e}	43.6 ± 3.1^{f}	47.9 ± 2.1^{g}	33.7 ± 3.0^{cd}	28.7 ± 1.7^{ab}	30.7 ± 2.3^{bc}	27.0 ± 3.2^{a}	***
PUFA	26.5 ± 1.9^{a}	25.7 ± 2.5^{a}	25.60 ± 1.9^{a}	25.8 ± 1.1^{a}	34.8 ± 2.6^{b}	42.5 ± 1.4^{c}	32.4 ± 2.5^{b}	35.1 ± 4.0^{b}	***
n-6	19.1 ± 0.9^{b}	19.5 ± 1.5^{b}	19.3 ± 0.8^{b}	23.1 ± 0.8^{c}	28.9 ± 1.8^{d}	40.2 ± 1.4^{e}	16.6 ± 1.1^{a}	15.2 ± 1.2^{a}	***
n-3	7.4 ± 1.8^{b}	6.2 ± 1.2^{b}	6.3 ± 1.3^{b}	2.7 ± 0.4^{a}	5.9 ± 1.1^{b}	2.3 ± 0.2^{a}	15.8 ± 2.6^{c}	19.9 ± 3.6^{d}	***
PUFA/SFA	0.7 ± 0.1^{a}	0.7 ± 0.1^{a}	0.8 ± 0.1^{b}	1.0 ± 0.1^{c}	1.1 ± 0.1^{d}	1.5 ± 0.1^{e}	0.9 ± 0.1^{bc}	0.9 ± 0.1^{bc}	***
n-6/n-3	2.8 ± 0.8^{b}	3.2 ± 0.5^{b}	3.2 ± 0.8^{b}	8.7 ± 1.1^{d}	5.1 ± 1.0^{c}	17.5 ± 1.9^{e}	1.1 ± 0.2^{a}	0.8 ± 0.2^{a}	***

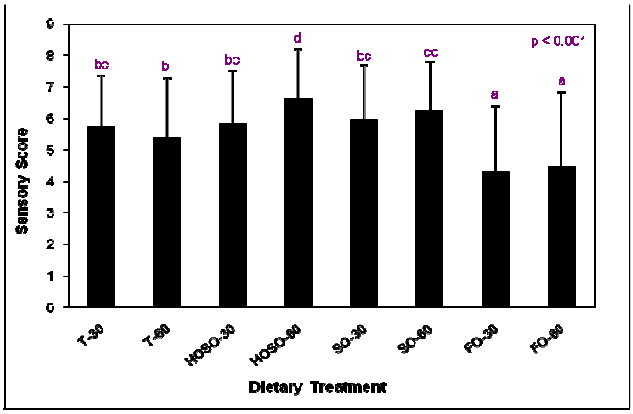

Fig. 1 The effect of different dietary lipid sources and inclusion levels (30 and 60 g/kg) on the respondents (n=75) preferences of chicken breast meat

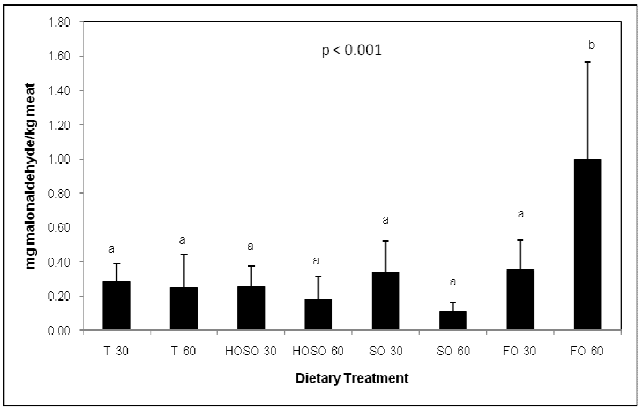

Fig. 2 TBARS value (mg malonaldehyde / kg meat) of chicken from different dietary treatments stored at 4°C for 7 days

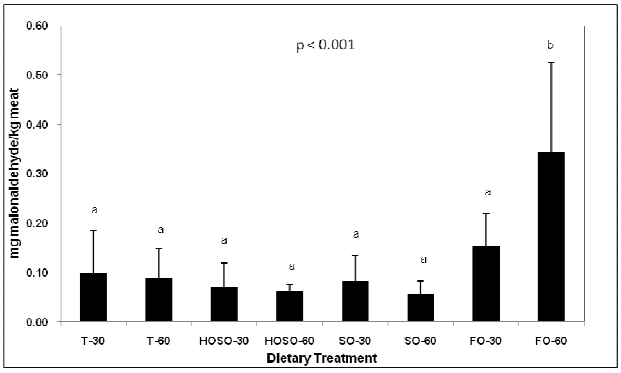

Fig. 3 TBARS value (mg malonaldehyde / kg meat) of vacuum sealed chicken breast from different dietary treatments stored at –18 ^{o}C for 100 days

than that of thighs and breasts that were stored under oxygen permeable overwrap film at 4^{o}C for 7 days for all treatments. In the case of the FO treatments this packaging effect was especially very noticeable.

IV. CONCLUSIONS

This research demonstrated that it is possible to utilize dietary intervention to improve the health properties of chicken breast meat by the inclusion of omega-9 (HOSO) or omega-3 (FO) in poultry diets.

Dietary inclusion of HOSO was the most preferred, while the inclusion of FO was the least preferred, irrespective of dietary inclusion level. These results suggested that dietary lipid sources could be used to manipulate the sensory characteristics of broiler breast meat according to consumer preferences.

Thigh and breast cuts from birds receiving saturated (T), mono-unsaturated oils (HOSO) and polyunsaturated SO (n-6) were more stable than cuts from birds receiving polyunsaturated FO rich in (n-3) fatty acids as part of their diet. These results indicate that dietary lipid sources and inclusion levels do influence the lipid oxidation processes of broiler meat and consequently the storage period of chicken meat.

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