Journal of Nutrition & Food Sciences
ISSN: 2155-9600

Mu and Kitts, J Nutr Food Sci 2018, 8:4
DOI: 10.4172/2155-9600.1000714

Research Article Open Access

Use of Soy Lecithin to Improve Nutritional Quality of Poultry Meats and its Effect on Stability and Sensory Attributes

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Abstract

Enhancing polyunsaturated fatty acid content of poultry meats can be associated with chemical oxidative stability and loss of sensory quality. In this study, broiler breast and leg muscle meats were examined from birds fed graded levels of soy lecithin {e.g. 0% (0L); 25% (25L); 50% (50L); 100% (100L)}, as a replacement for tallow in a standard poultry diet. Poultry breast and leg meats were analyzed for fatty acid content and oxidation products (TBARS), in freshly cooked and also on 5-day cold storage products, respectively. Cook-loss of meats were significantly ($P<0.05$) higher in birds fed the lecithin diets; this corresponded to relatively lower ($P<0.05$) phospholipids content remaining in cooked meats, compared to tallow fed controls. PUFAs consisting of linoleic and α-linolenic (α-LA) specifically, were both significantly ($P<0.05$) higher in breast and leg muscle meats, respectively, when derived from birds fed 50-100% soy lecithin replacement diets. Presence of highly unsaturated omega-3 was negligible and no change occurred with feeding diets. Increases in total PUFA content corresponded to reductions in MUFA with no changes in SFAs in lecithin fed birds. Changes in P/S ratios in 5-day refrigerated stored, cooked breast and leg products derived from birds fed lecithin were not significant from non-stored samples. TBARs content, corrected to MDA, in both cooked breast and leg muscle meats from tallow fed birds increased ($P<0.05$) to a higher extent over a 3 to 5-day storage period, compared to counterparts derived from the lecithin fed diets. This result indicated an antioxidant effect of feeding lecithin on both PUFA retention and reduced MDA. Descriptive sensory analysis with panelists trained to rank for lipid oxidation identified significant changes in flavor in 5-day refrigerated meats (e.g. cardboard flavor, oxidized aftertaste and sour taste) compared to lecithin fed counterparts.

Keywords: Soy lecithin; Poultry meats; Oxidative stability

Introduction

The increased recognition of notable health benefits afforded to consumers with higher dietary intakes of polyunsaturated fatty acids, aimed specifically at an optimal 3-5 to 1 ratio of omega-6 to omega-3 fatty acid [1-6] has generated considerable interest in the functional food industry [7]. Strategies to achieve this goal have included omega-3 fatty acid food formulations that rely on blending of oils which are rich in both fish and vegetable omega-3 fatty acid sources [8,9], use of microencapsulated omega-3 fatty acids [10,11] and feeding of domestic animal livestock with omega-3 PUFA- rich oil sources that will result in a specific alteration in the omega-3 content of the derived food product [12-14]. In this last example, the basis of the research efforts stems from the fact that presently a significant portion of the average North American diet includes food products derived from terrestrial livestock [15] and that North American consumers are less likely to choose diets that contain high amounts of oil fish [16].

Inclusion of essential oils in poultry diets has been successful to fortify the PUFA content [17,18]. Linoleic (C18:2, n-6) and α-LA (C18:3, n-3) are both essential fatty acids found in lecithin co-products derived from this edible oil [19]. The presence of high PUFA content with limited antioxidant capacity can lead to unwanted adverse changes in product quality associated with increased susceptibility to lipid oxidation [20]. Oxidation reactions in foods generally lead to generation of undesirable odors, flavors as well as potential risks to consumer safety, attributed to secondary products, such as malonaldehyde [21-24]. Monitoring lipid oxidation reactions in muscle foods can be achieved using the thiobarbituric acid (TBA) test for major secondary lipid oxidation products, or alternatively, using sensory evaluation analysis for perceived changes in flavor and odor in cooked meat products [25].

Soy lecithin, along with other sources of lecithin such as corn, rapeseed, sunflower and egg yolk, is rich in PUFA. Feeding soy-lecithin to broiler chickens can alter key events in hepatic gene expression that are linked to changes in lipid metabolism [26]. Antioxidant behavior of lecithin derived from vegetable oil [27], has potential synergistic actions with α-tocopherol to stabilize PUFAs in specific lipid oxidation studies [28-31]. The antioxidant capacity of lecithin could therefore also be considered a secondary added value, important for deriving a functional food from poultry meats that will rely on the retention of the value-added PUFA-nutrient components. For example, lipid oxidation reactions are enhanced in enriched PUFA poultry meats, thus requiring some stabilization at either the stage of diet ingredient formulation or with post-slaughter application of products [20]. Many workers have shown a positive effect of α-tocopherol in reducing the rate of lipid oxidation in poultry meats that enable extended shelf-life [32,33]. Administering the antioxidant to poultry diets produces better results for stabilizing lipids against oxidative processes in meat products, since a greater even distribution of the antioxidant can be obtained compared to adding it directly to the product. The purpose of the present study was to examine the stability and acceptability of omega-3 enriched poultry meat derived from poultry fed soy lecithin. Assessment of stability of both breast and leg meats was done in cooked and cooked-stored samples.

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Received June 26, 2018; **Accepted** July 16, 2018; **Published** July 31, 2018

Citation: Mu K, Kitts DD (2018) Use of Soy Lecithin to Improve Nutritional Quality of Poultry Meats and its Effect on Stability and Sensory Attributes. J Nutr Food Sci 8: 714. doi: 10.4172/2155-9600.1000714

Materials and Methods

Birds and diets

A total of twenty-four hundred (2400), newly-hatched, sexed (1200 males, 1200 females) Hubbard Hi-Y broiler chicks were used in this study. The broiler chickens were fed 4 diets with varying levels of dietary soy lecithin (donated by Archer Daniels Midland Co, Decatur, I.L., U.S.A.) to replace tallow in the diets (e.g. diets were: 0% lecithin, 100% tallow (0L); 25% lecithin, 75% tallow (25L); 50% lecithin, 50% tallow (50L); and 100% lecithin, 0% tallow (100L) (Table 1). Birds were fed a crumbled 22% protein diet from day 0 to day 21 (starter, S), a pelleted 21% protein (grower, G) diet fed from day 21 to day 34, and a pelleted 19% protein finished diet from day 35 until the completion of the trial at day 39 (finish, F). The diets were randomly assigned by @RAND procedure of Quattro Pro (v.5) software (Ottawa, Ontario, Canada). The housing of birds and feeding trials were conducted under veterinarian supervision by Drs. Stewart Ritchie and William Cox, at Canadian Poultry Consultants, Ltd., Abbotsford, B.C., Canada. After 39 days, the chickens were killed at a local commercial processor, and the carcasses were cut into breast and leg samples at 4°C, individually wrapped in thin polyethylene films, packed in 3 ml black polyethylene bags, and finally stored at –30C, until analysis began.

Processing broiler meats

Leg and breast samples from three different birds were thawed for 15 hours at 4°C. treatment and prepared for chemical and sensory analyses after cooking. Both leg and breast samples were steamed until the internal temperature reached 60°C; with further cooking continued for 10 minutes. After steam cooking all meat samples were cooled to 40°C (internal temperature) using room temperature, then cut into one-inch cubes and served immediately to the panelists. Parallel samples were stored for 14 days at 4°C. No sensory experiments were conducted on those particular samples.

Diet Ingredient	Ingredient Inclusion (%)			
	0L‡	25L	50L	100L
Corn†§	43.08	43.08	43.08	43.08
Wheat	15.00	15.00	15.00	15.00
Soybean Meal†§	30.00	30.00	30.00	30.00
Meat Meal	7.50	7.50	7.50	7.50
Salt	0.34	0.34	0.34	0.34
Limestone	0.48	0.505	0.530	0.58
Dicalcium Phosphate	0.43	0.368	0.205	0.18
Alimet	0.14	0.14	0.14	0.14
Trace Mineral Premix	0.20	0.20	0.20	0.20
Vitamin Premix	0.10	0.10	0.10	0.10
Coxistac	0.10	0.10	0.10	0.10
Stafac 44	0.05	0.05	0.05	0.05
Lecithin†§	0.00	0.625	1.250	2.5
Tallow	2.5	1.875	1.250	0.00
Choline Chloride	0.082	0.061	0.041	0.00
Sand	0.00	0.058	0.116	0.232

‡0L = 0% lecithin, 100% tallow; 25L = 25% lecithin, 75% tallow; 50L = 50% lecithin, 50% tallow; 100L = 100% lecithin, 0% tallow.

†Grower diet; Corn = 47.30; Soybean Meal = 25.00; Lecithin 0L = 0.00, 25L = 0.875, 50L = 1.750, 100L = 3.50.

§Finished diet; Corn = 52.59; Soybean Meal = 19.80; Lecithin 0L = 0.00, 25L = 0.875, 50L = 1.750, 100L = 3.50.

Table 1: Components of experimental broiler diet formulations.

Chemical analyses:

Total crude lipids were extracted from the cooked breast and leg samples using 2:1 chloroform/methanol (v/v), according to the method of Folch and others [34]. Unsaponifiable fat in the samples was extracted with petroleum ether and phospholipid content was measured using an enzymatic colorimetric test kit (Boehringer Mannheim, Mannheim, Germany). Saponifiable fat remaining was analyzed for fatty acids by gas chromatography (Shimadzu Model GC-17A, Mandel Scientific Co., Guelph, Ontario, Canada) according to the method described by Soewono and Kitts [9]. Percentages of different fatty acids present in the leg and breast samples were calculated by the area under each peak in the chromatogram. PUFA n-3 fatty acids were present <0.01% total fatty acids.

MDA was measured using the Thiobarbituric Acid assay, (TBA) procedure of Buege and Aust [35]. TBA values were converted to MDA values (mg MDA/100 g meat) from a standard curve prepared with tetraethoxy propane (MDA standard).

Sensory analysis

Sensory studies were conducted using Descriptive Analytical Testing. Twelve trained male and female panelists in the age group of 20-35 were used in the taste panel. Training provided panelists with terminology to describe the characteristics of the samples and to interpret the scales used in the study. Breast and leg samples were coded with three digit random numbers according to the diet treatment the birds had been fed. The samples were evaluated for different attributes using a 10 inch unstructured line scale anchored at each end. The terminology used to describe aroma were "chicken aroma", "cardboard" and "oxidized." The attributes for flavor included "cardboard", "oxidized" (aftertaste) and "sour." "First impression tenderness" and "initial juiciness" were used to describe texture. The distance from the left hand anchor on the line scale to the panellists' mark was used as the score (0 = none, and 10 = intense). Panelists were given free access to distilled water and unsalted crackers during the tasting to help cleanse their palates.

Statistical analysis

The effects of four dietary treatments supplemented with varying proportion of soy lecithin on the fatty acid and TBAR content in broiler chicken leg and breast muscle meats were analyzed by a one-way analysis of variance (ANOVA). Significant differences among the treatment mean values were determined using Tukey' test (MINITAB Version 17- Minitab Inc. State College, PA, USA). In all cases, $P<0.05$ was considered statistically significant.

Results

Diets

Table 1 shows the components of the experimental, starter (S), growing (G) and finishing (F) broiler diets, formulated to contain a range of dietary lecithin to tallow proportions that resulted in final lecithin inclusions of 0-100%. Small changes in the diet compositions were made to meet requirements of birds at each level of development, with Table 2 summarizing the energy density and nutrient composition of S, G, and F diets. Small increment increases in metabolizable energy for G and F diets complemented similar small increases in total crude lipid, whereas crude protein, and fat soluble vitamin levels were decreased, albeit slightly. A more comprehensive analysis of the fatty acid composition of S, G and F diets containing specific graded amounts of lecithin is presented in Table 3. All three experimental diet designed

to meet the stage of growth of experimental birds with increasing lecithin content produced significant increases in linoleic (C18:2, n-6), the primary PUFA; relatively lower, but also increased contents of linolenic (C18:3, n-3 and arachidonic (C20:4, n-6), respectively. Changes in PUFA content corresponded to similar magnitudes of change in MUFAs ($P<0.05$) and reflect the contribution of PUFA derived from lecithin and loss of oleic acid derived from tallow. These modifications in fatty acid contents did not alter appreciably the gross energy and total crude lipid contents of respective diets.

The color characteristics and cook-loss parameters of the broiler breast and leg muscle meats following steam cooking is given in Table 4 respectively. There was no change in Hunter lab L, a, b values for both cooked breast and leg samples derived from birds fed the different lecithin containing diets. Cook-loss was significantly ($P<0.05$) greater in breast meats derived from birds fed the soy lecithin containing diets; but not influenced by the level of lecithin fed. A parallel decline ($P<0.05$) in phospholipid content of breast tissue occurred with cook-loss only in breast meats obtained from birds fed higher lecithin content diets (Table 4). A similar effect was observed for both cook-losses and total phospholipid content in cooked leg meats derived from birds fed 50% and 100% lecithin diets (Table 4).

The relative changes in fatty acid composition in breast meats derived from broiler diets varying in lecithin content are presented in Table 5a. Breast meats derived from birds fed a minimum of 50% lecithin supplement in the diet showed significant increases ($P<0.05$) in both C18:2 and C18:3 PUFAs, which also corresponded to a relatively higher P/S ratio. Refrigeration storing of the cooked breast meat (Table 5b) did not have produce a change in PUFA content compared to fresh cooked meats (Table 5a), indicating stability of these essential fatty acids during cold storage. A similar comparison was done on cooked leg meats that were examined fresh (e.g. non-stored -Table 6a) and also after refrigeration storage (Table 6b). Both fresh and stored cooked broiler leg meats had elevated C18:2, n-6 and C18:3, n-3 PUFA content in birds fed a minimum of 50% lecithin supplement that corresponded to higher P/S ratio. Unlike the breast muscle however; a small loss of both C18:2, n-6 and C18:3, n-3 PUFAs were observed in leg meats that were refrigeration stored after cooking. In breast meat, the relative reduction in MUFA content paralleled an increase ($P<0.05$) in PUFA in birds fed 100% lecithin supplement, regardless of having cold storage after cooking (Table 7a, b- $P<0.05$). A similar set of changes in MUFA content were observed in leg meats collected from birds fed 100% lecithin supplement, regardless of storage (Table 7a, b- $P<0.05$). No change in saturated fatty acid content was observed with lecithin feeding in both breast and leg meats (Table 7a and 7b).

Nutrient	Experimental Diets		
	Starter	Grower	Finished
DM [1] Metabolizable Energy (kcal/kg)	87 3000	86 3090	86 3160
Crude Protein (%)	23.0	21.0	19.0
Lysine (%)	1.23	1.09	0.95
Methionine (%)	0.45	0.44	0.38
Methionine + Cysteine (%)	0.82	0.75	0.67
Arginine (%)	1.56	1.39	1.22
Threonine (%)	0.88	0.80	0.71
Crude Fat (%)	5.25-5.41	6.33-6.55	6.52-6.74
Crude Fibre (%)	2.80	2.70	2.60
Calcium (%)	1.00	0.95	0.95
Total Phosphorus (%)	0.79	0.75	0.73
Available Phosphorus (%)	0.45	0.43	0.43
Sodium (%)	0.18	0.17	0.17
Vitamin A (IU/Kg)	11500	10000	8000
Vitamin D (IU/Kg)	3000	2700	2160
Vitamin E (IU/Kg)	50	40	32

[1]DM=% Dry Weight.

Table 2: Nutrient content of experimental broiler diets.

Lipid oxidation as measured by TBARs in both cooked breast and leg muscle meats derived from tallow fed birds showed a significant temporal increase ($P<0.05$) over a 5-day refrigeration storage period. Birds fed 100% lecithin supplement had reduced TBARs in cooked breast meat after 5-days of refrigerated storage compared to the tallow fed counterparts (Figure 1a). The protection against TBARs formation with lecithin supplement feeding was more pronounced in leg meats after 5- day refrigerated storage (Figure 1b). This effect was observed regardless of the level of lecithin supplement fed.

Sensory evolution data conducted with 12 trained panelists on qualities of oxidation of 5-day stored cooked broiler breast derived from birds fed diets on different levels of lecithin is shown in spider diagrams Figure 2a. The counterpart sensory analysis conducted on leg meat is shown in Figure 2b. Negligible differences in ranking of aroma, flavor and texture descriptors were obtained for breast meats derived from lecithin supplement treatments compared to tallow-fed controls. The one exception however; was with the cooked breast meat that was obtained from broilers fed the 100% lecithin supplement diet, where panelists perceived that this breast meat contained a significantly ($P<0.05$) reduced cardboard aroma compared to counterparts fed the tallow control diet. There were also no differences in texture, as measured using first impression tenderness or initial juiciness in breast meat collected from birds fed varying levels of lecithin supplement. Cooked leg muscle also gave no noticeable differences in aroma, flavor or texture between lecithin supplement and tallow dietary treatments.

Discussion

The physical and chemical attributes of both breast and leg muscle were relatively the same in broilers fed different levels of dietary lecithin supplement, in comparison to tallow fed birds. The higher cook-loss in muscle meats derived from birds fed higher dietary lecithin levels could explain the relatively lower phospholipid content in cooked meats. The phospholipid content of both cooked leg and breast muscle meats were indeed lower than the non-cooked samples. In the cooked, 5-day stored muscle meats, the phospholipid content was lowered to an even greater extent than the fresh cooked meats; again, suggesting that the combination of drip-loss and possibly lipid oxidation could of attributed to this effect. Cooking liberates inorganic iron from myoglobin and iron-containing pigments in the meat [21] thus producing a situation where metal ion induced lipid oxidation can occur in cooked muscle; especially when antioxidant capacity is limiting. The fact that further loss of phospholipid was not as apparent in 5-day stored breast and leg meats suggests that the antioxidant potential of lecithin was carried over during storage, thus stabilizing the PUFA content, as indexed by the little change in phospholipid content.

The quality and composition of fat deposition in poultry is principally affected by the diet composition and the metabolism of the bird [22]. Several studies have shown that altering the source of dietary lipid for birds will result in a body fat composition that mirrors the fat source [28,33,36,37]. Important changes in fatty acid composition related to enhanced PUFA content of breast meat

	Proportion of Lecithin in Diet[2]			
	0L	**25L**	**50L**	**100L**
		S Diets[3]		
Gross energy[4]	4692.2	4630.6	4642.2	4603.3
Total crude lipids[5]	6.08	6.30	6.12	6.12
		Fatty acid[6]		
12:0	0.044 ± 0.001	0.051 ± 0.009	0.021 ± 0.032	0.026 ± 0.018
14:0	0.953 ± 0.039^{a}	0.874 ± 0.016^{b}	0.769 ± 0.006^{c}	0.677 ± 0.003^{d}
16:0	19.931 ± 0.003^{a}	19.153 ± 0.051^{b}	18.609 ± 0.052^{c}	18.032 ± 0.037^{d}
16:1	2.193 ± 0.001^{a}	1.837 ± 0.047^{b}	1.472 ± 0.043^{c}	0.826 ± 0.018^{d}
18:0	8.529 ± 0.005^{a}	8.656 ± 0.155^{a}	8.258 ± 0.064^{b}	7.671 ± 0.003^{c}
18:1	36.583 ± 0.002^{a}	34.453 ± 0.173^{b}	31.705 ± 0.079^{c}	25.201 ± 0.044^{d}
18:2	29.241 ± 0.001^{a}	32.25 ± 0.026^{b}	36.044 ± 0.059^{c}	43.691 ± 0.049^{d}
18:3	2.222 ± 0.003^{a}	2.417 ± 0.004^{b}	2.803 ± 0.002^{c}	3.541 ± 0.007^{d}
20:0	0.305 ± 0.003^{a}	0.309 ± 0.002^{a}	0.318 ± 0.006^{b}	0.335 ± 0.002^{c}
		G Diet		
Gross energy	4725.6	5139.4	4672.8	4639.4
Total crude lipids	5.694	6.929	6.708	6.755
		Fatty acid		
12:0	0.040 ± 0.002^{a}	0.036 ± 0.010^{b}	0.061 ± 0.001^{c}	0.081 ± 0.001^{d}
14:0	0.773 ± 0.003^{a}	0.752 ± 0.007^{a}	0.617 ± 0.023^{b}	0.432 ± 0.007^{c}
16:0	18.229 ± 0.021^{a}	18.955 ± 0.057^{b}	18.350 ± 0.028^{c}	17.384 ± 0.002^{d}
16:1	2.131 ± 0.043^{a}	1.817 ± 0.006^{b}	1.423 ± 0.019^{c}	0.576 ± 0.016^{d}
18:0	9.520 ± 0.025^{a}	9.125 ± 0.077^{b}	8.218 ± 0.008^{c}	6.923 ± 0.038^{d}
18:1	40.401 ± 0.033^{a}	37.139 ± 0.058^{b}	33.377 ± 0.094^{c}	24.414 ± 0.020^{d}
18:2	26.811 ± 0.007^{a}	29.811 ± 0.086^{b}	34.818 ± 0.042^{c}	45.841 ± 0.007^{d}
18:3	1.816 ± 0.011^{a}	2.056 ± 0.019^{b}	2.805 ± 0.001^{c}	4.000 ± 0.001^{d}
20:0	0.314 ± 0.010^{a}	0.317 ± 0.002^{a}	0.349 ± 0.004^{b}	0.349 ± 0.006^{b}
		F Diet		
Gross energy	4691.7	4692.2	4675.0	4643.3
Total crude lipids	6.765	6.747	6.320	6.228
		Fatty acid[§]		
12:0	0.049 ± 0.001^{a}	0.049 ± 0.001^{a}	0.056 ± 0.002^{b}	0.053 ± 0.001^{b}
14:0	0.905 ± 0.002^{a}	0.857 ± 0.004^{b}	0.760 ± 0.002^{c}	0.647 ± 0.001^{d}
16:0	19.351 ± 0.225^{a}	18.890 ± 0.049^{b}	18.550 ± 0.004^{c}	17.446 ± 0.001^{d}
16:1	2.181 ± 0.009^{a}	1.832 ± 0.008^{b}	1.473 ± 0.001^{c}	0.644 ± 0.001^{d}
18:0	9.359 ± 0.019^{a}	8.862 ± 0.006^{b}	8.551 ± 0.001^{c}	7.089 ± 0.001^{d}
18:1	40.739 ± 0.304^{a}	37.343 ± 0.065^{b}	34.012 ± 0.001^{c}	25.260 ± 0.001^{d}
18:2	25.582 ± 0.118^{a}	29.672 ± 0.004^{b}	33.692 ± 0.004^{c}	44.844 ± 0.001^{d}
18:3	1.686 ± 0.014^{a}	2.146 ± 0.001^{b}	2.549 ± 0.002^{c}	3.547 ± 0.175^{d}
20:0	0.354 ± 0.004^{a}	0.347 ± 0.008^{ab}	0.361 ± 0.002^{bc}	0.368 ± 0.002^{c}

[1§]Data (Mean ± SD, n=10) are weight percentage of total fatty acids;

[a,b,c]Data in the same row with unlike superscripts are significantly different ($p \leq 0.05$).

[2]0L = 0% lecithin, 100% tallow; 25L = 25% lecithin, 75% tallow; 50L = 50% lecithin, 50% tallow; 100L = 100% lecithin, 0% tallow

[3]Diets: S=Starter; G=Grower; F=Finish. [4] GE=Gross Energy (kilocalories/kg), [5] TCL= Total crude lipid (% wet basis), [6] FA=Fatty acid (% total FA).

Table 3. Energy and fatty acid profile of starter, grower and finish experimental broiler diets[1].

in particular cannot be attributed only to dietary modification with lecithin supplement feeding, but also to controlling lipid peroxidation. The combination of cooking and a 5-day cold storage of muscle meats reduced PUFA content in both breast and leg muscles in the tallow, more so than lecithin supplemented broilers, indicating that lecithin could be used to render ready-to-eat poultry meats more acceptable due to reducing potential for lipid oxidation. The best results were: however, obtained when the tallow component was completely replacing in the diet with lecithin; this corresponding to reduced loss of PUFA and reduced production of lipid oxidation products.

Heat treatment, such as steaming of the poultry muscle meats increases subsequent TBAR content, a finding which corresponds to the fact that poultry meat products have a relatively low α-tocopherol content and higher PUFA content [21]; this being a feature of poultry meats being potentially more susceptible to lipid oxidation reactions than other muscle meats [38]. Moreover, cooked leg muscle meat produced a greater TBARs content, than the corresponding treatments of breast muscle, which can be explained by the fact that poultry leg muscle contains greater prooxidant (e.g. heme iron) [39], which when released would catalyze peroxidation reactions. In tallow fed birds, a relatively lower P/S

a. Parameter	Proportion of Lecithin in Diet			
	0L[2]	25L	50L	100L
Color: L	40.90 ± 1.20	40.86 ± 0.71	38.34 ± 0.68	39.54 ± 0.44
a	4.02 ± 0.49	3.37 ± 0.39	4.58 ± 0.35	4.52 ± 0.27
b	9.73 ± 0.23	9.47 ± 0.33	9.45 ± 0.12	9.71 ± 0.29
Cook Loss[3]	26.06 ± 1.10[a]	31.10 ± 0.68[b]	31.39 ± 0.72[b]	32.03 ± 0.37[b]
PhL[4]	1.10 ± 0.01[a]	1.07 ± 0.02[a]	0.98 ± 0.02[b]	0.85 ± 0.01[c]

b. Parameter	Proportion of Lecithin in Diet			
	0L[2]	25L	50L	100L
Color: L	39.49 ± 1.01	40.77 ± 0.73	38.69 ± 0.71	40.63 ± 0.71
a	6.28 ± 0.29	5.70 ± 0.21	6.11 ± 0.21	5.83 ± 0.14
b	9.26 ± 0.23	9.14 ± 0.24	9.12 ± 0.24	10.04 ± 0.19
Cook Loss[3]	25.83 ±1.05[a]	31.89 ± 0.48[b]	29.88 ± 1.10[b]	29.52 ± 0.50[b]
PhL[4]	1.66 ± 0.04[a]	2.19 ± 0.08[b]	0.92 ± 0.02[c]	0.86 ± 0.02[c]

[1]Results are means ± means (N=10 birds/group)

[a,b,c]Data in the same row with unlike superscripts are significantly different ($p \leq 0.05$).

[2]0L = 0% lecithin, 100% tallow; 25L = 25% lecithin, 75% tallow; 50L = 50% lecithin, 50% tallow; 100L = 100% lecithin, 0% tallow.

[3]Results given as g/100g

[4]PhL = Phospholipids (mg/g)

Table 4: Physical and chemical attributes of breast(A) and leg(B) meat of birds fed experimental diets[1].

Fatty Acid	Proportion of Lecithin in Diet							
	0L‡		25L		50L		100L	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
12:0	0.025[ab]	0.007	0.038[ab]	0.020	0.054[a]	0.011	0.020[b]	0.004
14:0	0.783[a]	0.010	0.707[a]	0.059	0.964[b]	0.033	0.79[a]	0.034
16:0	25.448[a]	0.873	23.701[ab]	0.662	23.690[b]	0.386	24.126[ab]	0.442
16:1	5.772[a]	0.739	4.737[ab]	0.209	4.223[ab]	0.683	3.934[b]	0.708
18:0	9.380	1.375	9.272	1.052	11.082	0.509	10.522	0.769
18:1	43.715[a]	1.480	42.404[a]	3.01	39.122[b]	1.78	35.745[b]	1.27
18:2	14.286[a]	1.498	17.882[ab]	2.343	19.964[b]	2.281	23.298[c]	2.359
18:3	0.560[a]	0.086	1.154[b]	0.190	1.239[b]	0.165	1.690[c]	0.289
20:4	0.098[a]	0.024	0.095[a]	0.026	0.124[a]	0.011	0.107[a]	0.002
(P/S)†	0.415[a]	0.041	0.503[b]	0.067	0.590[b]	0.043	0.700[c]	0.082

Table 5a: Fatty acid profile of non-stored, cooked breast muscle§

Fatty Acid	Proportion of Lecithin in Diet							
	0L‡		25L		50L		100L	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
12:0	0.157[a]	0.039	0.177[a]	0.066	0.027[b]	0.003	0.072[b]	0.022
14:0	1.016[a]	0.099	0.869[b]	0.001	1.004[ab]	0.026	0.839[b]	0.010
16:0	24.911[a]	0.310	23.626[b]	0.515	23.825[b]	0.184	24.249[ab]	0.333
16:1	5.188[a]	0.595	4.276[a]	0.367	4.478[a]	0.943	3.314[b]	0.131
18:0	10.930	0.682	10.664	0.054	11.295	0.738	10.383	0.075
18:1	42.769[a]	1.784	41.887[a]	1.651	39.231[a]	1.598	33.810[b]	0.860
18:2	14.846[a]	1.336	17.643[a]	0.948	18.889[b]	1.580	25.488[c]	0.495
18:3	0.785[a]	0.039	1.073[b]	0.123	1.147[c]	0.059	1.759[d]	0.117
20:4	0.062[a]	0.030	0.085[b]	0.010	0.103[b]	0.019	0.083[b]	0.028
(P/S)†	0.421[a]	0.030	0.528[b]	0.020	0.552[b]	0.031	0.764[c]	0.009

§Values represent mean ± S.D. (n=3) of weight percentage of total fatty acids.

‡0L=0% lecithin, 100% tallow; 25L=25% lecithin, 75% tallow; 50L=50% lecithin, 50% tallow; 100L=100% lecithin, 0% tallow.

†Polyunsaturate (P) to Saturate (S) ratio.

[a,b,c]Mean values within the same row with unlike superscript letter were significantly different ($p \leq 0.05$).

Table 5b: Fatty acid profile of 5-day stored, cooked breast muscle§.

Fatty Acid	Proportion of Lecithin in Diet							
	0L‡		25L		50L		100L	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
12:0	0.033	0.019	0.051	0.014	0.039	0.007	0.025	0.007
14:0	0.796[a]	0.066	0.642[b]	0.058	0.669[ab]	0.035	0.594[b]	0.025
16:0	25.779	2.79	23.543	0.553	23.101	0.296	23.376	1.314
16:1	7.502[a]	1.54	5.845[ab]	0.303	5.676[ab]	0.705	3.745[b]	0.340
18:0	7.320	0.905	7.112	0.473	7.114	0.083	7.640	0.389
18:1	48.276[a]	3.35	44.773[a]	2.32	43.505[a]	1.32	36.680[b]	1.41
18:2	12.656[a]	2.10	18.608[a]	3.01	18.449[a]	2.02	26.865[b]	1.75
18:3	0.899[a]	0.076	1.346[a]	0.330	1.338[a]	0.157	1.995[b]	0.026
20:4	0.069[a]	0.008	0.077[a]	0.004	0.076[a]	0.003	0.084[a]	0.006
(P/S)	0.405[a]	0.097	0.607[a]	0.128	0.638[a]	0.074	0.910[b]	0.050

Table 6a: Fatty acid profile of cooked non-stored, cooked leg muscle§.

Fatty Acid	Proportion of Lecithin in Diet							
	0L‡		25L		50L		100L	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
12:0	0.064[a]	0.008	0.045[ab]	0.013	0.028[b]	0.003	0.027[b]	0.006
14:0	0.085[a]	0.044	0.624[b]	0.058	0.760[b]	0.163	0.635[b]	0.029
16:0	25.225	1.710	23.249	0.401	23.241	0.317	23.511	0.147
16:1	7.307[a]	0.631	5.685[a]	0.147	5.604[a]	0.808	4.615[b]	0.806
18:0	7.176	0.243	7.548	0.637	7.336	0.043	7.946	0.035
18:1	46.812[a]	0.993	42.441[a]	1.125	43.891[a]	0.829	40.022[b]	3.834
18:2	12.362[a]	1.680	19.033[a]	2.661	17.793[a]	1.619	21.600[b]	4.037
18:3	0.818[a]	0.051	1.357[a]	0.304	1.265[a]	0.132	1.604[b]	0.394
20:4	0.059[a]	0.017	0.057[a]	0.007	0.080[a]	0.045	0.060[a]	0.002
(P/S)†	0.406[a]	0.070	0.649[a]	0.112	0.606[a]	0.059	0.710[a]	0.132

§Values represent mean ± S.D. (n=3) of weight percentage of total fatty acids.

‡0L = 0% lecithin, 100% tallow; 25L = 25% lecithin, 75% tallow; 50L = 50% lecithin, 50% tallow; 100L = 100% lecithin, 0% tallow.

†Polyunsaturates (P) to Saturates (S) ratio.

[a,b,c] Mean values within the same row with unlike superscript letter were significantly different ($p \leq 0.05$).

Table 6b: Fatty acid profile of 5-day stored, cooked leg muscle§.

Treatment[2]				
Cooked-NS	Saturated[3]	Monounsaturate[4]	Polyunsaturate[5]	P/S
Breast				
0L	39.51 ± 2.07[a]	42.16 ± 2.70[a]	18.32 ± 0.65[a]	0.42±0.04
25L	37.25 ± 2.46[a]	44.89 ± 2.26[a]	17.93 ± 0.49[a]	0.56±0.07
50L	36.10 ± 1.10[a]	43.84 ± 0.56[a]	20.02 ± 1.10[b]	0.59±0.07
100L	38.70 ± 1.13[a]	37.06 ± 2.04[b]	24.24 ± 0.92[b]	0.70±0.08
Leg				
0L	34.89 ± 0.33[a]	47.85 ± 2.57[a]	16.70 ± 3.20[a]	0.41±0.10
25L	34.31 ± 0.32[a]	45.11 ± 0.48[a]	20.58 ± 0.44[a]	0.64±0.13
50L	34.88 ± 1.84[a]	44.53 ± 1.40[a]	20.61 ± 1.59[a]	0.64±0.07
100L	35.63 ± 1.56[a]	37.95 ± 2.03[a]	26.42 ± 0.96[b]	0.91±0.05

[1]Data (Mean ± SD, n=10) are weight percentage of total fatty acids;

[a,b,c]Data in the same row with unlike superscripts are significantly different ($p \leq 0.05$).

[2]0L=0% lecithin, 100% tallow; 25L=25% lecithin, 75% tallow; 50L = 50% lecithin, 50% tallow; 100L = 100% lecithin, 0% tallow

[3]Saturated fatty acids: lauric (12:0), myristic (14:0), palmitic (16:0), stearic (18:0), arachidonic (20:0);

[4]Monounsaturated fatty acids: palmitoleic (16:1), oleic (18:1);

[5]Total Polyunsaturated fatty acids: linoleic (18:2, n-6), α-linolenic (18:3, n-3), arachidonic (C20:4, n-6)

Table 7a: Total Saturated, Monounsaturated and Polyunsaturated Fatty acid content (%) in non-stored, cooked breast and leg meats[1].

ratio in cooked poultry meats paralleled an increase in TBARs, a dominant secondary lipid oxidation product. In the present study, the higher P/S ratio in meats recovered from lecithin supplemented fed broilers was retained indicating a possible antioxidant property of the dietary lecithin.

The descriptors used in this study for assessing meat quality are common for sensory assessment of poultry meats [40]. For example, in the present study, sensory attributes for odour were evaluated using descriptors such as "chicken aroma," "cardboard aroma," and "oxidized aroma"; all defined to characterize the smell and odor of cooked

Treatment[2]				
Cooked-5-day stored muscle-	**Saturated[3]**	**Monounsaturate[4]**	**Polyunsaturate[5]**	**P/S**
Breast				
0L	39.14 ± 3.12[a]	45.33 ± 3.91[a]	15.51 ± 0.79[a]	0.42 ±0.030
25L	37.16 ± 3.2[a]	46.56 ± 2.41[a]	16.38 ± 0.93[a]	0.53 ±0.020
50L	37.58 ± 4.09[a]	45.04 ± 2.56[a]	17.33 ± 1.61[a]	0.55 ±0.031
100L	39.74 ± 1.21[a]	38.29 ± 1.27[b]	21.90 ± 0.91[b]	0.76 ±0.0090
Leg				
0L	35.68 ± 0.72[a]	48.92 ± 3.37[a]	15.46 ± 2.76[a]	0.41 ±0.070
25L	33.03 ± 2.48[a]	48.19 ± 2.94[a]	18.75 ± 1.06[a]	0.65 ±0.11
50L	36.31 ± 1.05[a]	43.38 ± 0.69[b]	20.31 ± 0.35[b]	0.61 ±0.059
100L	33.50 ± 2.53[a]	41.78 ± 2.58[b]	24.72 ± 0.49[b]	0.72 ±0.13

[1]Data (Mean ± SD, n=10) are weight percentage of total fatty acids;

[a,b,c]Data in the same row with unlike superscripts are significantly different ($p \leq 0.05$).

[2]0L = 0% lecithin, 100% tallow; 25L = 25% lecithin, 75% tallow; 50L = 50% lecithin, 50% tallow; 100L = 100% lecithin, 0% tallow.

[3]Saturated fatty acids: lauric (12:0), myristic (14:0), palmitic (16:0), stearic (18:0), arachidonic (20:0);

[4]Monounsaturated fatty acids: palmitoleic (16:1), oleic (18:1);

[5]Total Polyunsaturated fatty acids: linoleic (18:2, n-6), α-linolenic (18:3, n-3), arachidonic (C20:4, n-6).

Table 7b: Total Saturated, Monounsaturated and Polyunsaturated Fatty acid content (%) in cooked, 5-day stored breast and leg meats[1].

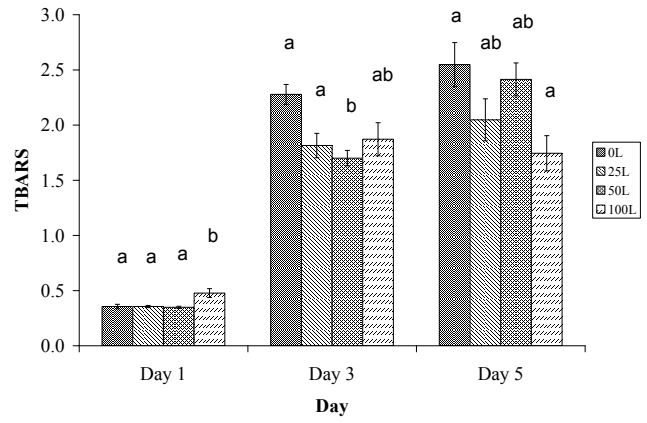

Figure 1a: Lipid oxidation is expressed as TBARS (mg MDA/kg) meat in cooked breast of birds fed diets containing lecithin.

[a-c]Dietary treatments with different letters are significantly different ($p<0.05$). 0L = 0% lecithin, 100% tallow; 25L = 25% lecithin, 75% tallow; 50L = 50% lecithin, 50% tallow; 100L = 100% lecithin, 0% tallow.

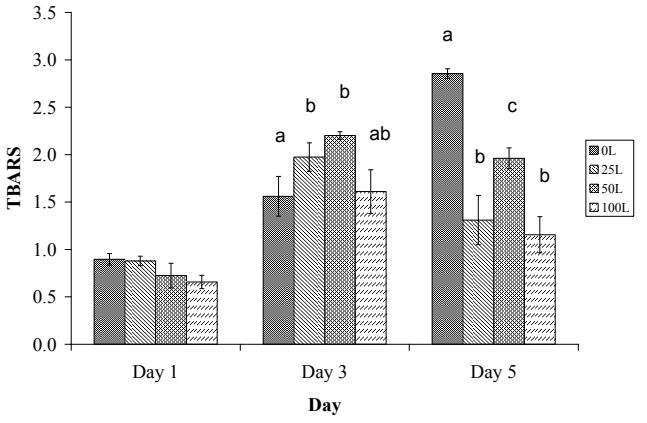

Figure 1b: Lipid oxidation expressed as TBARS (mg MDA/kg) in cooked leg muscle of birds fed diets containing lecithin.

[a-c]Dietary treatments with different letters are significantly different ($p<0.05$). 0L = 0% lecithin, 100% tallow; 25L = 25% lecithin, 75% tallow; 50L = 50% lecithin, 50% tallow; 100L = 100% lecithin, 0% tallow.

chicken muscle and the aroma of oxidized fat. Using these descriptors, negligible differences in aroma, flavour, and texture were perceived by panellists, thus confirming that the level of oxidation of cooked broiler breast and leg tissue was minimal in the lecithin fed birds. Using the sensory results that indicated detection of lipid oxidation off flavor, with the finding that showed increased levels of TBARs in the 5-day stored chicken breast and leg muscle of tallow fed birds in this study, points to the fact that quality attributes of cold stored poultry meat products can be lost without the protection provided by antioxidant agents incorporated into the meat systems. Feeding lecithin, albeit at a level that replaced tallow, limited the amount of lipid oxidation in breast meat products to an extent that was detectable by sensory evaluation. This was less apparent in the poultry leg meats. King and others [41] have reported antioxidant activity of phospholipids, total lipids, and neutral lipids extracted from bluefish (*Pomatomus saltaatrix*) in a salmon oil model system. The phospholipid components exhibited the highest antioxidant capacity among other lipids. Nwosu and others [42] also studied the antioxidant property of phospholipids in a bulk fish oil system and suggested that the choline or ethanolamine head group of the phospholipid molecule had an integral part in the antioxidant behaviour of phospholipids. The observed enhanced oxidative stability of the oil was attributed to a chelating function of the phospholipids amine group towards prooxidant metal ions. Cho and others [43] also found that phospholipid composition influenced oxidative stability of lipids from squid tissues, with phosphatidylethanolamine being superior to phosphatidylcholine at stabilizing lipid in squid viscera. In the present study, cooking poultry meat products, combined with subsequent 5-day storage, would also be expected to liberate bound transition metal ions from denatured protein, as described above, thus resulted in greater liberation of free metal ions for potential prooxidant activity. The fact that both chemical and sensory indices of lipid oxidation from muscle lipids derived from birds fed the higher lecithin containing diets did not exhibit the same level of development of lipid oxidation in breast and leg muscles indicates that stabilization of the

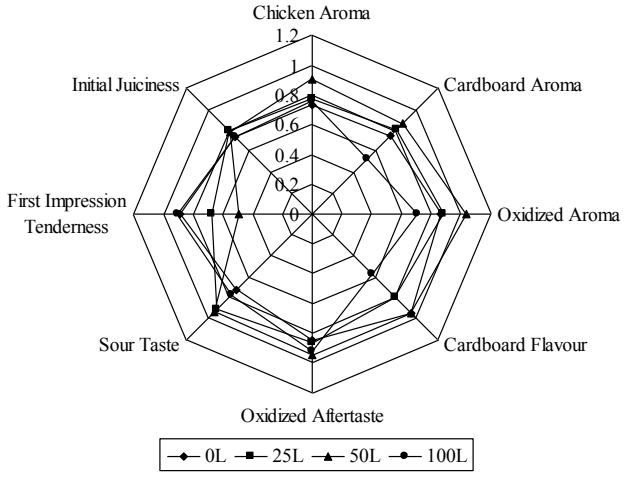

Figure 2a: Sensory scored for aroma, taste, flavour and texture attributes of cooked breast (A) of birds fed diets containing lecithin 0L = 0% lecithin, 100% tallow; 25L = 25% lecithin, 75% tallow; 50L = 50% lecithin, 50% tallow; 100L = 100% lecithin, 0% tallow.

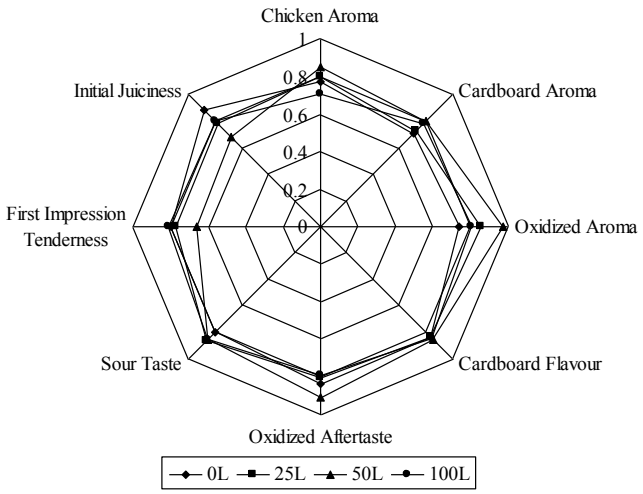

Figure 2b: Sensory scored for aroma, taste, flavour and texture attributes of cooked leg (B) muscle of birds fed diets containing lecithin 0L = 0% lecithin, 100% tallow; 25L = 25% lecithin, 75% tallow; 50L = 50% lecithin, 50% tallow; 100L = 100% lecithin, 0% tallow.

enhanced PUFA content was achieved by the dietary lecithin fed to the birds. This occurred despite the fact that some of the phospholipid incorporated in muscle systems was lost in drip-loss after cooking; however, what was retained indeed provided protection against lipid peroxidation.

Conclusion

Replacement of tallow with soy lecithin in diets of broiler chickens successfully enhanced the total PUFA contents of both breast and leg muscles. As lecithin replaced tallow in the diet, the levels of TBARS in the cooked breast and leg muscles were reduced, which paralleled the enhanced PUFA content. However, as expected, the TBARs content of the leg muscle was generally found to be greater than that of the breast muscle. The data from the sensory evaluation confirmed the oxidative stability of the cooked, 5-day stored broiler breast meat, characterized from typical aroma, flavour, and texture descriptors, could be detected. The greater oxidative stability of the cooked broiler muscle derived from birds fed the high lecithin supplemented diets, is consistent with the potential antioxidant effect of lecithin.

Acknowledgments

Authors wish to thank Drs. Stewart Ritchie (DVM) and William Cox (DVM) from Canadian Poultry Consultants, Ltd. 30325 Canary Court, Abbotsford, B.C. V4X 2N4 for their generous support and assistance in conducting this study. Study was funded in part by NSERC-Discovery and UBC-Vitamin grants to DDK.

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