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Oxidative Stability of Cooked Chicken Breast Burgers Obtained from Organic, Free-range and Conventionally Reared Animals

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Abstract: The oxidative stability of cooked chicken breast burgers from chickens reared on organic (n=3), free-range (n=3), and conventional (n=3) diets was determined. α-Tocopherol and fatty acid concentrations were also determined. Organic, free-range and conventional chicken breasts were obtained from local retail outlets. Significant ($P<0.05$) differences in α-tocopherol concentrations were found between samples indicating that α-tocopherol concentrations were dependant on the individual source diet rather than whether the sample was of organic, free-range or conventional origin. Concentrations of fatty acids also appeared to be dependent on individual source diets. Compared with other samples, the three organic samples and one free-range sample had lower concentrations of monounsaturated and polyunsaturated fatty acids of n-3 and n-6 series. Burgers were manufactured, cooked and stored in a modified atmosphere (20% CO_2: 80% N_2), held at 4 °C under fluorescent light and oxidation monitored on days 1, 3, 5 and 7. Significant ($P<0.05$) differences were found in lipid oxidation (monitored by malondialdehyde thiobarbituric acid (MDA-TBA) values) between samples on days 1, 3, 5 and 7 of refrigerated storage. α-Tocopherol concentration and MDA-TBA values appeared to be related in most samples. In general, MDA-TBA values were in the following order throughout the selected storage period: organic>free-range>conventional. It was concluded that cooked breast burgers from broilers fed organic diets had a lower shelf-life (oxidative) stability compared with cooked breast burgers from broilers free-range and conventional diets. Stability, in the present work, appeared to be related more to α-tocopherol concentration than to fatty acids.

Key words: Oxidative stability, cooked chicken burgers, organic, free-range, conventional

Introduction

In recent years there has been an increased consumer demand for convenience or "case ready" meat and meat products requiring minimal home preparation (Stubbs *et al.,* 2002). Accordingly, less poultry is marketed today as whole carcasses and more as a variety of further prepared or fully cooked products (Ang and Lyon, 1990). Parallel to the demand for convenience foods has been a dramatic growth, at 20-30% annually, in consumer demand for organic foods (Bord Bia, 2000). Reasons for this growth include an increasing consumer demand for natural and healthy foods plus a growing consumer concern about the ethical quality of meat (Moosa, 1999; Nilzén *et al.,* 2001).

While the sales of organic foods has grown globally, scientific studies comparing quality and safety issues of organic foods versus conventionally produced foods has not kept pace with this developed and evolving consumer food trend. From limited research carried out in the area of muscle foods, Nilzén *et al.* (2001) and Castellini *et al.* (2002) compared meat from conventionally reared animals with that of meat from animals reared on either free-range or organic production systems. They suggested that meat produced from free-range or organic systems may be more prone to lipid oxidation. Lipid oxidation is one of the primary causes of quality deterioration in meat and meat products and can result in the production of off-flavours and odours, increased drip losses, loss of pigment, polyunsaturated fatty acids and fat soluble vitamins, and a decrease in consumer acceptability (Morrissey *et al.,* 1994; Higgins *et al.,* 1998; Jensen *et al.,* 1998; Lawlor *et al.,* 1999). Pre-cooked meat food products have been shown to be highly susceptible to lipid oxidation during refrigerated and frozen storage (Wen *et al.,* 1996). It is not surprising, therefore, that the measurement and prevention of lipid oxidation in meat products is of primary concern in the meat industry. Sheehy *et al.* (1993) reported that higher concentrations of the lipid soluble antioxidant vitamin, vitamin E (α-tocopherol), in raw and cooked chicken resulted in reduced lipid oxidation (monitored by TBARS numbers) during refrigerated and frozen storage. The protective effect of α-tocopherol against lipid oxidation has been reported by other workers (Faustman *et al.,* 1989; Asghar *et al.,* 1990; King *et al.,* 1995; Higgins *et al.*, 1998; Lawlor *et al.,* 2000).

Due to increased consumer demand for meat from an organic and free-range origin and its availability to the consumer as a range of "case-ready" meat and meat products, information is urgently required by the meat industry to determine the oxidative, and shelf-life, stability

of such products in the market-place as well as providing consumers with factual information relating to organic/conventional food quality issues. The objectives of the present study were to determine and compare differences in lipid oxidation, during simulated retail display, in cooked chicken breast burgers obtained from organic, free-range and conventionally reared animals. α-Tocopherol and fatty acid profiles and concentrations of organic, free-range and conventional samples were also determined to determine whether differences in or α-tocopherol concentrations and/or fatty acids affected the oxidative stability of samples during refrigerated retail storage.

Materials and Methods

Reagents: All chemicals used were "AnalaR" grade with the exception of hexane and methanol which were "HPLC" grade. Chemicals were obtained from BDH Chemicals Ltd., Poole, Dorset, England; Rathburn Chemicals Ltd., Walkerburn, Scotland and Sigma Chemical Co. Ltd., Poole, Dorset, England.

Samples: Nine raw chicken breast samples (three organic, three free-range and three conventional) were purchased from local retail outlets (Table 1). Samples were vacuum-packed using a Webomatic type D463 (Werner bonk, Bochum, Germany) vacuum packer and blast frozen using a Froster type BF 35 (Cross Refrigeration, Mallow Road, Cork, Ireland). Samples were subsequently stored in a chest freezer at -20 °C until analysis. The vacuum packaging material consisted of Cryovac (W. R. Grace Europe Inc., Lausanne, Switzerland) (45 cm^3/m^2/24 h at STP).

α-Tocopherol in muscle tissue: α-Tocopherol was extracted from muscle following the method of Buttriss and Diplock (1984). α-Tocopherol content was determined by a modification of the method described by Sheehy *et al.* (1991). High performance liquid chromatography (HPLC) analysis was performed using a Waters (Model 510) HPLC pump and a Waters (Model 717plus) autosampler. The column was a Machery-Nagel Nucleosil C_{18} column (250 x 4 mm i.d., 5 µm particle size). The detector was a Waters (Model 486) tunable absorbance detector and the wavelength used was 292 nm. Chromatograms were recorded using the Millennium 32 Chromatography Manager (Millipore Corporation, Milford, MA, USA). α-Tocopherol concentration in tissue samples was determined using a standard curve.

Determination of fatty acids: Fatty acid methyl esters were prepared using a modification of the method of Slover and Lanza (1979). Gas chromatography analysis was performed using a Shimadzu (Model GC-14A) gas chromatograph with flame ionisation detection, equipped with a Shimadzu (Model AOC-17) auto injector. The column used was a DB-WAX (30 m x 0.32 mm i.d., film thickness 0.25 µm, J&W Scientific, Folsom, CA, USA). The carrier gas was nitrogen at a pressure of 1 kg/cm^2. Oven temperature programming was as follows: 50-200 °C at 10 °C/min, held for 35 min; 200-230 °C at 10 °C/min and held isothermally at 230 °C for 20 min. The injector port and detector temperature was 250 °C. Chromatograms were processed using the Millennium 2010 Chromotography Manager (Millipore Corporation, Milford, MA, USA).

Preparation of cooked burgers: Each chicken breast (-20 °C) was allowed to defrost overnight at 4 °C. Samples were trimmed of extramuscular fat and minced with 5% water and 1% NaCl, using a conventional meat grinder, (Biro, Marblehead, OH) through a plate with 4.8 mm diameter holes. The blended muscle samples were immediately made into burgers using a conventional burger maker (MINISTEAK, O. L. Smith & Co. Ltd., Italy). Burgers were cooked by placing them on a hot-plate (GICO, Vazzola, Italy). Temperature probes were used during cooking to ensure that the internal temperature of the meat reached 72 °C (Higgins *et al.*, 1998). Burgers were cooled, placed on polystyrene/EVOH/polyethylene trays and a MAP of 80% N_2, 20% CO_2). Samples were stored in a retail display cabinet at 4 °C under fluorescent lighting (616 lux) for 7 days.

Oxidative stability of cooked burgers: The oxidative stability of MAP cooked burgers during refrigerated display at 4 °C was determined on days 1, 3, 5 and 7 following the 2-thiobarbituric acid distillation method of Tarladgis *et al.* (1960) as modified by Ke *et al.* (1977). First derivative spectral analysis was carried out as outlined by Wen *et al.* (1997). All analyses were performed in duplicate.

Preparation of standard curves for first derivative spectrophotometry: The standard curve for first derivative spectrophotometry and the recovery of malonaldehyde from the distillation procedure were prepared using the methods described by Lawlor *et al.* (2000). Values were expressed as mg of malondialdehyde thiobarbituric acid (MDA-TBA) per kg of muscle.

Statistical analysis: One-way analysis of variance (ANOVA) was carried out using SPSS v 10.0 (SPSS Inc., Chicago, USA) software package. Duncan's multiple range test was used to compare different means. Level of significance was set at 5%.

Results and Discussion

α-Tocopherol concentration of raw muscle: The mean α-tocopherol concentrations of organic, free-range and

Table 1: Chicken breast samples used in the study, their corresponding codes, description, country of origin and retail source

Number	Code	Description	Country of Origin	Source*
1	O-Fr(a)	Organic	France	a
2	O-Fr(b)	Organic	France	b
3	O-NI(c)	Organic	Northern Ireland	c
4	FR-UK(a)	Free-range	UK	a
5	FR-NI(b)	Free-range	Northern Ireland	b
6	FR-Fr(b)	Free-range	France	b
7	C-Ir(a)	Conventional	Ireland	a
8	C-Ir(b)	Conventional	Ireland	b
9	C-Ir(c)	Conventional	Ireland	c

*Source refers to the different commercial suppliers.

Table 2: Mean and standard error (SE) α-tocopherol concentration (mg/kg) of raw chicken breasts from organic, free-range and conventionally reared animals. Means are the result of four analyses. Average values for each group are also shown. For identification of codes refer to Table 1.

Number	Code	Mean (SE)
1	O-Fr(a)	3.29 (0.57)^{a}
2	O-Fr(b)	2.01 (0.44)^{a}
3	O-NI(c)	5.67 (0.74)^{b}
4	FR-UK(a)	2.50 (0.09)^{a}
5	FR-NI(b)	6.60 (0.53)^{b}
6	FR-Fr(b)	11.62 (0.52)^{d}
7	C-Ir(a)	3.28 (0.32)^{a}
8	C-Ir(b)	6.77 (1.20)^{b}
9	C-Ir(c)	9.12 (1.36)^{c}

^{a,b,c,d}Means, within a column, without a common superscript differ significantly (P<0.05).

conventional raw chicken breast samples are shown in Table 2. Significant (P<0.05) differences in α-tocopherol concentrations were found indicating that α-tocopherol concentration depended on individual source diet. Organic samples 1[O-Fr(a)] and 2[O-Fr(b)] had significantly (P<0.05) lower α-tocopherol concentrations (3.29 and 2.01 mg/kg, respectively) compared with the remaining organic sample 3, O-NI(c) (5.67 mg/kg). Significant (P<0.05) differences existed between the three free-range samples. α-Tocopherol concentrations in these samples ranged from 2.50 mg/kg, in sample 4 [FR-UK(a)], to 11.62 mg/kg in sample 6 [FR-Fr(b)]. Conventional sample 7 [C-Ir(a)] had a significantly (P<0.05) lower α-tocopherol concentration (3.28 mg/kg) compared with samples 8 [C-Ir(b)] and 9 [C-Ir(c)] with 6.77 and 9.12 mg/kg α-tocopherol, respectively.

The vitamin E concentration in muscle depends on the muscle characteristics, level of vitamin E in the diet and the duration of feeding (Jensen *et al.*, 1998; Morrissey *et al.*, 2000). Nilzén *et al.* (2001) investigated the influence of free-range rearing, RN genotype, and gender on different pig meat quality traits including vitamin E concentration. These authors reported that outdoor rearing with access to green feed resulted in an increased concentration of vitamin E compared with pigs that had been reared indoors and fed a conventional pig feeding mixture. In the present study, because all samples were purchased from a commercial origin, no information was available on the composition of the diets fed to broilers from the different sources. However, it is clear from Table 2 that the diets fed to broilers varied considerably in their vitamin E content and α-tocopherol concentration was therefore source dependent. Further work is needed to determine the composition of the individual source diets and its relationship to the final vitamin E content in raw breast samples.

Fatty acid profiles of raw muscle: The fatty acid profiles of raw breast muscle, obtained from chickens reared on organic, free-range or conventional diets is shown in Table 3.

Organic samples 1[O-Fr(a)], 2 [O-Fr(b)], 3 [O-NI(c)] and free-range sample 6 [FR-Fr(b)] had the lowest concentrations of monounsaturated and polyunsaturated fatty acids of n-3 and n-6 series (Table 3). Free-range samples 4 [FR-UK(a)] and 5 [FR-NI(b)] and commercial sample 8 [C-Ir(b)], on the other hand, had the highest concentrations of these fatty acids. Previous workers have shown that different dietary regimes can result in differences in fatty acid profiles (Nilzén *et al.*, 2001; Castellini *et al.*, 2002). Castellini *et al.* (2002) reported that, compared with breast muscle from controls, chicken breast muscle from organically fed chickens had a lower sum of saturated and monounsaturated fatty acids and a higher sum of polyunsaturated fatty acids. Results of the present study showed that rather than differences existing between organic, free-range and conventional "groups", differences were more likely to depend on individual source diets.

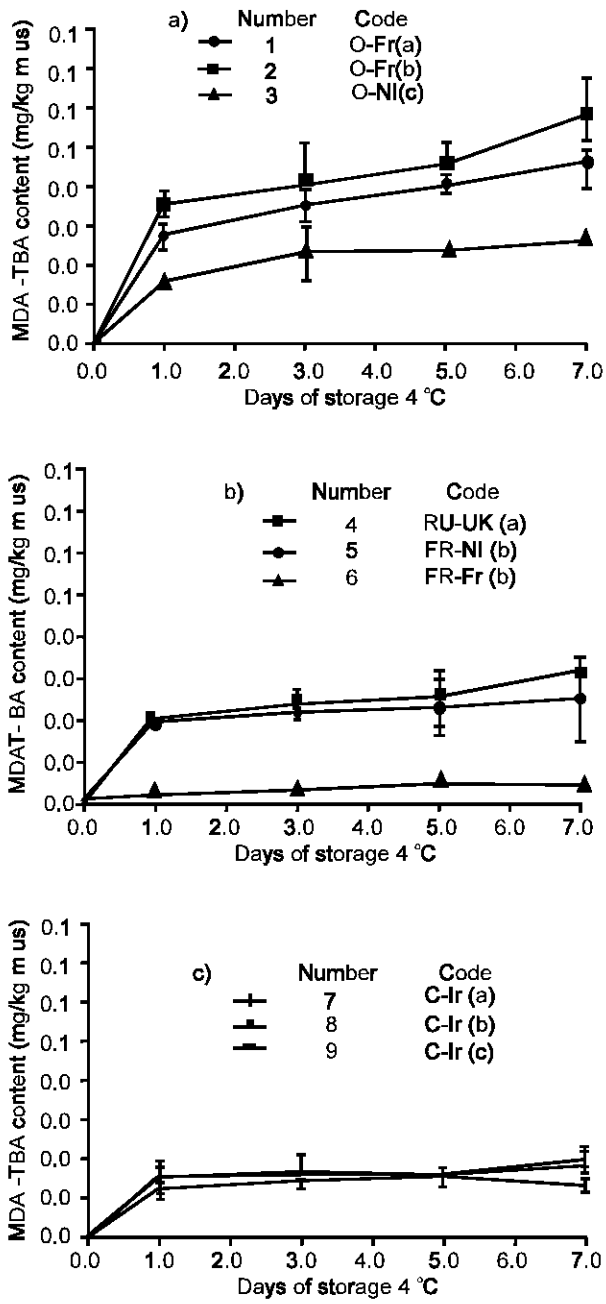

Fig. 1: Time course of lipid oxidation measured over a 7 day storage period at 4 °C using derivative spectrophotometry and expressed as MDA-TBA content (mg/kg muscle) in cooked chicken burgers obtained from animals fed (a) organic, (b) free-range, and (c) conventional diets. Standard error is indicated by bars.

Oxidative stability: The time course of lipid oxidation measured over a 7 day period, of lipid oxidation in organic, free-range and conventional cooked chicken breast burgers stored under MAP at 4 °C can be seen in Fig. 1.

Significant ($P<0.05$) differences in MDA-TBA values were found between organic, free-range and conventional samples on days, 1, 3, 5 and 7 of refrigerated storage at 4 °C. In general, MDA-TBA values were in the following order: organic > free-range > conventional. Compared with other samples, organic samples 1 [O-Fr(a)] and 2 [O-Fr(b)] had significantly ($P<0.05$) higher MDA-TBA values on days 1, 3, 5 and 7. Organic samples 1 [O-Fr(a)] and 2 [O-Fr(b)] had two of the lowest α-tocopherol concentrations of samples investigated (Table 2). The relationship between α-tocopherol concentration and level of lipid oxidation in meat has been widely reported (Monahan *et al.*, 1990; Jensen *et al.*, 1997; Lawlor *et al.*, 2000). However, conventional sample 7 [C-Ir(b)] had low vitamin E levels and low MDA-TBA values throughout storage. Free-range sample 6 [FR-Fr(b)] and conventional sample 9 [C-Ir(c)] had the lowest MDA-TBA values throughout storage. Of all samples investigated, free-range sample 6 [FR-Fr(b)] and conventional sample 9 [C-Ir(c)] had two of the highest concentrations of α-tocopherol. Castellini *et al.* (2002) investigated and compared the effects of conventional and organic production on broiler carcass and meat quality. They reported that meat from organic chickens had lower lipid stability (monitored by TBARS) compared with meat from chickens fed the conventional diet. These authors concluded that the reduced oxidative stability of organic samples could have been caused by their higher content of metallic ions (total and haem Fe), their higher degree of unsaturation of intramuscular lipids and the greater physical activity of the organic animals.

In the present work, organic samples 1 [O-Fr(a)] and 2 [O-Fr(b)] had two of the lower concentrations of α-tocopherol and monounsaturated and polyunsaturated fatty acids of all samples studied. These two samples had the highest MDA-TBA values throughout refrigerated storage. Free-range sample 6 [FR-Fr(b)] also had low concentrations of MUFA and PUFA, but along with the highest concentration of α-tocopherol, also had the lowest MDA-TBA values throughout refrigerated storage.

Conclusion: The oxidative stability of cooked chicken breast burgers from organic, free-range and conventionally reared animals, under retail display conditions were determined and compared. In general the extent of lipid oxidation of cooked chicken burgers was in the following order: organic < free-range < conventional. The α-tocopherol and fatty acid content appeared to be dependent on individual source diet and α-tocopherol content determined, to a large extent, the oxidative stability of samples. Therefore, although

Table 3: Fatty acid composition of raw chicken breasts from organic, free-range and conventionally reared animals. Values are in expressed as µg/g. For identification of codes refer to Table 1

		Fatty acids (mg/g)											
		Unsaturated			Monounsaturated			Polyunsaturated n-3			Polyunsaturated n-6		
No.	Sample code	C14:0	C16:0	C18:0	C16:1	C18:1	C18:3	C20:5	C22:4	C22:6	C18:2	C20:3	C20:4
1	O-Fr(a)	8.0^{a}	115.2^{a}	49.0^{a}	10.9^{a}	126.9^{a}	9.6^{a}	ND	ND	22.6	183.4^{a}	10.4^{a}	201.4^{a,b}
2	O-Fr(b)	18.4^{b}	305.9^{a,b}	155.7^{b}	56.5^{b}	534.9^{a}	55.3^{b}	17.8	ND	60.5	386.5^{a,b,c}	23.8^{b}	134.9^{a}
3	O-NI(c)	15.8^{b}	309.9^{a,b}	159.1^{b}	44.1^{a,b}	457.5^{a}	15.8^{a,b}	9.6	ND	34.4	348.7^{a,b}	16.8^{a,b}	236.9^{a,b,c}
4	FR-UK(a)	26.1^{c,d}	7.5.3^{c}	360.4^{c}	111.1^{c}	1310.3^{b}	45.8^{a,b}	57.8	28	204.6	648.9^{c}	46.0^{c}	365.7^{c,d}
5	FR-NI(b)	31.9^{d}	772.8^{c}	416.4^{c}	109.1^{c}	1538.3^{b,c}	92.2^{c}	43.4	39.7	180.5	1024.4^{d}	50.3^{c}	462.0^{d}
6	FR-Fr(b)	16.1^{b}	267.8^{a,b}	128.3^{a,b}	34.0^{a,b}	345.4^{a}	22.3^{a,b}	ND	ND	ND	323.9^{a,b}	22.4^{a,b}	223.3^{a,b}
7	C-Ir(a)	22.8^{b,c}	681.6^{c}	353.1^{c}	77.9^{b,c}	1412.9^{b,c}	39.7^{a,b}	45.3	12.9	157	578.4^{b,c}	42.9^{c}	307.5^{b,c}
8	C-Ir(b)	39.5^{e}	1154.6^{d}	531.2^{d}	169.2^{d}	1982.2^{c}	103.9^{c}	19.9	67.1	149.3	1178.2^{d}	53.0^{c}	616.9^{e}
9	C-Ir(c)	17.0^{b}	399.7^{b}	185.9^{b}	65.5^{b}	616.9^{a}	23.8^{a,b}	10.6	ND	48.8	484.3^{b,c}	22.0^{a,b}	252.5^{a,b,ca,}

$^{a, b, c, d}$ Means, within columns, without a common superscript differ significantly (P<0.05). ND - Not Detected

organic and free-range meat and meat products may control a higher market price meat manufacturers need to be aware that meat from these origins may also be more prone to the undesirable effects of lipid oxidation during refrigerated storage.

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